BACTERIOLOGY FOR NURSES

HARRY W. CAREY, M.D.

AN INTRODUCTION

TO

BACTERIOLOGY

FOR NURSES

BY

HARRY W. CAREY, A.B., M.D.

Former Assistant Bacteriologist, Bender Hygienic Laboratory, Albany, N. Y.;
Associate in Medicine, Samaritan Hospital, and City Bacteriologist,
Troy, N. Y.

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PREFACE.

MANY of the duties of the nurse require a knowledge of the principles of bacteriology in order to be performed intelligently. It is difficult, however, for anyone instructing nurses, to decide just how much of the subject to attempt to teach.

The basis of this book is the lecture notes that I have used during the last eight years in teaching the nurses of the Samaritan Hospital Training School. In incorporating them into book form I have endeavored to present clearly and in simple language that portion of the subject essential for the nurse to know. A few blank pages have been inserted at the end of each chapter for the convenience of the student in adding useful notes from time to time.

H. W. CAREY, M.D.

TROY, N. Y.

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CHAPTER I.

THE HISTORY OF BACTERIOLOGY.

THE history of this science is interesting because it tells how the study of bacteria developed from mere theories into a science based upon facts. Long before anything was known of the existence of germs, references could be found in the writings of the ancient Greeks discussing the possibility of disease passing from one person to another. The agent of infection was supposed to originate from the air or moisture.

The discovery of germs

With the instruments of ancient times it was impossible to see the minute living particles which we now know as germs; in fact, it is doubtful that such minute forms were thought of. The seventeenth century, however, marked a new era in the making of optical instruments. Anthony von Leeuwenhoeck in 1675, a linen draper of Amsterdam in Holland, succeeded in perfecting a lens of much greater magnifying power than those hitherto in use. By means of this lens he was able to see minute living animalcules in saliva, water, and other fluids, that were smaller than any seen before. The descriptions of the animalcules he saw were very accurate and correspond to some of the forms we recognize today.

The theory of spontaneous generation

The discovery of these minute living organisms provoked a great deal of discussion, as may be imagined. Perhaps the question most debated was

their source and mode of origin. Among the lowest forms of animal life known at that time were the maggots found in putrefying meat. It was supposed that they developed from the meat during the process of putrefaction. The animalcules of von Leeuwenhoeck too were believed to originate spontaneously. This theory of spontaneous generation held sway and, although there were many opposed to this doctrine, it was not until nearly a hundred years later that Spallanzani (1769), an Italian, tried by experiment to show that micro-organisms could not develop in this way. He took animal matter and mixed it with water in a flask. After boiling the mixture and sealing the neck of the flask he found that it could be kept for a long time without putrefying and without any micro-organisms developing in it. This experiment was subjected to much criticism, however, because the air so essential for the development of life was excluded by sealing the flask. This objection was met by modifying the experiment, first by admitting air that had passed through strong sulphuric acid, and later by filtering the air through cotton used to plug the mouth of the flask. It remained for Pasteur (1860) to settle the question beyond dispute by showing that the entrance of dust into mixtures that had been boiled was sufficient to set up putrefaction on account of the germs carried in with it. So long as the air was filtered free of germs by cotton plugs, just so long the mixtures remained free from growth.

Experiments proving spontaneous generation incorrect

These experiments had a far-reaching influence upon the conception of bacteriology, as may be imagined, and proved beyond question that *germs originate only from germs.* Upon this fact rest all our ideas of preventing the spread of disease and the aseptic precautions used in surgery.

Association of germs with cause of disease

The association of micro-organisms with the production of disease, conceived long before the organisms were seen, received much attention after the observations of von Leeuwenhoeck. During the next hundred years all sorts and kinds of disease were one after another attributed to the growth of germs in the body. Von Plenciz (1762), a physician of Vienna, was perhaps the foremost advocate of these new ideas of the causation of disease. He believed not only that germs gave rise to some diseases, but that each disease had its own particular germ which, after entering the body, developed and multiplied. These theories of von Plenciz were subjected to much ridicule, to be sure; but they continued to gain adherents nevertheless, and have proven, as we know, to be correct. Some years later Henle (1840) collected and published all the work that had been done up to that time, and pointed out that the causal relationship of germs to disease could not be proven simply by finding germs in the diseased tissues of the body, but that they must also be grown and studied outside of the body. Experiments to prove the doctrines of Henle were lacking chiefly because

the instruments and methods for studying germs at that time were inadequate.

In the next thirty to forty years many new methods were introduced which marked a rapid progress in the study of germs; for example, the use of aniline dyes for coloring germs so that they could be seen better under the microscope, and solid culture media on which germs could be cultivated and different kinds separated and studied. The development of these new methods was due chiefly to the genius of Koch, who also laid down certain laws or conditions which had to be fulfilled before any germ could be said to be the cause of any specific disease. With improved methods and appliances the relationship of germs to specific diseases could be proven experimentally, and the discovery of the germs of many diseases followed with great rapidity. Since 1879 the germs causing the following diseases have been discovered: Diphtheria, Leprosy, Typhoid Fever, Tuberculosis, Tetanus (Lockjaw), Influenza, Bubonic Plague, Cholera, Meningitis, Pneumonia, Syphilis, Gonorrhea, and others.

The study of the life history or biology of these germs has led to our present knowledge of the cause, the course, and ways of preventing most of the infectious diseases, and has put into the hands of physicians the means whereby the character of an infectious disease may be detected.

From this brief sketch it is easy to appreciate that bacteriology is, comparatively speaking, a new

science, and that its greatest progress has occurred in our time. It is advancing now even more rapidly than ever before along lines destined to be of the greatest service to humanity. Efforts are being directed particularly to the discovery of antitoxins and serums that will protect against the infectious diseases.

CHAPTER II.

THE CLASSIFICATION, MORPHOLOGY, BIOLOGY, AND DISTRIBUTION OF BACTERIA.

WE have referred to micro-organisms as germs, a popular term, but not exact enough for our use. The term "germs" may be taken to mean any microscopic organism, animal or vegetable.

In the animal kingdom the lowest forms of life are called Protozoa (sing. Protozoön), of which there are several types: Sarcodina, Mastigophora, and Sporozoa. The discussion of the protozoa will be reserved until a later chapter.

Classification of bacteria

In the vegetable kingdom we are particularly interested in the fungi, which are subdivided into Hyphomycetes or molds, Blastomycetes or yeasts, and Schizomycetes or bacteria. The bacteria are by far the most important of the three; so we will confine ourselves solely to them for the present, and leave the yeasts and molds for a subsequent chapter.

Definition of bacterium

The word bacterium is derived from a Greek word meaning a rod; the plural form is bacteria. A bacterium may be defined as a minute living organism composed of one cell, belonging to the vegetable kingdom.

Structure

The structure of bacteria is very simple as we know it. The vital part of the cell which controls its activities is called the nucleus, and is usually situated at or near the center. Surrounding this is a

Fig. 1.—Different forms of bacteria. *A,* cocci; *B,* bacilli; *C,* spirilla. (*Baumgarten.*)

transparent and homogeneous substance called the protoplasm, which takes up the nutriment from without. At the periphery the protoplasm becomes denser and forms what is known as the capsule of the cell. The amount of protoplasm is very small, so that under the microscope there appears to be only nucleus and capsule.

The morphological characters of bacteria—that is, their size and shape—vary greatly, and upon this basis it is convenient to subdivide them into three types:—

Morphology

A. Coccus; plural form, Cocci.
B. Bacillus; plural form, Bacilli.
C. Spirillum; plural form, Spirilla.

The cocci are shaped like berries, that is, about spherical. They may be flattened on one side or concave, or split like a coffee-bean. They may be arranged in pairs called diplococci; in fours, tetracocci; or in cubes, sarcinæ. They are commonly arranged in long strings or chains termed streptococci, or in masses often likened to bunches of grapes, staphylococci. The bacilli are rod-shaped, sometimes slightly curved, and vary greatly in length, from $^1/_{1000}$ to $^1/_{25000}$ of an inch. They occasionally form in chains or rows. The spirilla are spiral or corkscrew-shaped, as the name implies. They vary both in length and in the number of spirals. Of these three types the bacilli are by far the most numerous and the spirilla the least numerous. The types are

not interchangeable; so it is not possible for a coccus to become a bacillus or a bacillus a spirillum.

In order to see them it is necessary to use a microscope of high magnifying power; indeed, it is highly probable that some forms of bacteria are so small that they cannot be seen with any of the microscopes that we have.

Bacteria reproduce by what is known as binary fission; that means a pinching off or splitting in the middle, each part developing into another organism. Reproduction occurs only under conditions favorable for bacterial growth. The rate of division or multiplication is very fast, sometimes every fifteen minutes. Starting with one organism one can imagine what an enormous number may develop in twenty-four hours at this rate.

Reproduction

Under conditions unfavorable to the life and growth some kinds of bacteria may assume another form to avoid extermination. This is called spore formation. These spores are round or oval bodies, much smaller than the organism from which they originate, and differ from them in having a thick protective capsule that enables them to withstand heat, sunlight and, in fact, any harmful influence. The spores may be formed inside the body of the organism and extruded from it, or the whole organism may be changed into a spore. As a rule, one spore forms in each organism, but in some kinds of bacteria several may be formed. When conditions again become favorable for growth the spore may

Spore formation

elongate and gradually assume its original shape, or the bacillus may form inside the body of the spore and burst the capsule. (See Fig. 9.)

Motility

The power of locomotion is observed in some bacteria. When watched under the microscope they may be seen moving across the field of vision. The motility depends upon small, threadlike processes projecting from the bodies of the bacteria, called flagella (singular form, flagellum), which by moving to and fro with a whiplike motion propel the bodies forward. The flagella may be single or multiple, and may be placed at one or both ends or all around the bacterium. The motility of spirilla is somewhat different. The amount of protoplasm about the nucleus is much more abundant than in the bacilli, and this by an undulating, wavelike motion drives the organism forward. The phenomenon of locomotion is limited to bacilli and spirilla; the cocci do not move. (See Fig. 6, page 57.)

Properties of bacteria

The property of producing pigment or coloring matter is peculiar to some kinds of bacteria. The pigment may be entirely within the body of the organism or it may be set free from it and color the material upon which the bacteria are growing. Other properties of bacteria that may be mentioned are the fermentation of sugars into alcohol, the production of characteristic odors, the formation of acids and alkalies, and the production of light. The property of producing poisons is perhaps the most important of all, and will be spoken of in detail in the chapter on immunity.

From what has been said of the properties of bacteria it is possible to make a number of classifications; for example, there are the spore-forming and non-spore-forming bacteria, the motile and non-motile, fermenting and non-fermenting, acid forming and alkali forming, etc. By observing these properties of bacteria it is possible to identify them.

Nutriment

Like all plants bacteria require food, which must be in very simple form to enable them to assimilate it. Oxygen, carbon, nitrogen, hydrogen, and chemical salts form their chief food. They derive the oxygen from the air, although some varieties of bacteria take it from substances in which the oxygen is combined with other chemical elements. The bacteria that take their oxygen from the air are called aërobic bacteria, while those taking it from substances containing it in combined form are called anaërobic bacteria. The line of demarcation between the aërobic and the anaërobic bacteria is not fixed, as sometimes bacteria thriving best under aërobic conditions will, nevertheless, grow in the absence of free oxygen and *vice versâ*. These are spoken of as facultative anaërobes or aërobes, as the case may be. The carbon is obtained from proteids, carbohydrates (starchy substances), or fats. The hydrogen is derived for the most part from water. The nitrogen is obtained from proteids such as albumin. The salts required for nutrition are sodium, potassium, and magnesium.

Certain conditions of environment exert a great deal of influence upon the life and growth of bacteria.

Influence of environment

The influence of temperature is most important. Bacteria thrive best at 37.5° C., and as the temperature varies above or below this point growth is retarded. A temperature of 62° C. will kill most bacteria. Low temperatures are not so destructive, for by experiments it has been proven that a temperature of 200 degrees below zero (centigrade) will not kill all bacteria.

Moisture is essential for the growth of bacteria, as the food material upon which bacteria thrive must be in solution. The reaction of the food material is of considerable moment, for bacteria will not grow if too much acid or alkali is present. A neutral or slightly acid reaction gives the best growth.

Cultivation

In order to cultivate bacteria, substances must be used from which they can obtain the proper nutriment. Such substances when made artificially are called culture media, and they may be solid or fluid. The solid media are employed when a surface growth is desired, the bacteria being rubbed on the surface. The common kinds of solid media are agar-agar, gelatin, and coagulated blood-serum. Fluid media are used for the determination of acid formation, fermentation, coagulation, and motility; those most often used are milk and bouillon. The media are prepared in the laboratory. After the ingredients have been dissolved by boiling, the whole is filtered, run into test-tubes, plugged with cotton, and finally sterilized by steam under pressure in order that no bacteria may develop in it except those introduced for the purpose of study.

The distribution of bacteria in nature is prac-

tically universal. They are found in the soil, in the air, in the food we eat, and in the water we drink. In fact, wherever plants and animals live, bacteria are found. Their distribution, however, is not equal, being more numerous in some places than others. The soil is the chief home of bacteria on account of the large amount of animal matter in it. They are present in greatest number at the surface and diminish in the deeper layers. The reason for this is that the closely packed particles of the soil will not permit the bacteria to penetrate beyond the superficial layers. Surface water which contains bacteria in great number is rendered practically free from them by this filtering action of the soil.

Distribution **Soil**

In the air the number of bacteria is directly proportional to the amount of dust. When the wind blows the dust into the air, large numbers of bacteria are carried with it; but when the air is quiet, the bacteria by force of gravity settle to the ground. It is a well-known fact that bacteria will not leave a moist surface; so in wet weather the number of bacteria in the air is considerably less than at other times. At high altitudes and far out at sea there are practically no bacteria in the air, as there is no dust. The bacteria in the soil and air do not exist as a rule in their tru form, but as spores which develop into bacteria when the conditions for growth become favorable.

Air

Water as it leaves the clouds in the form of rain is free from bacteria, but as the rain-drops approach the earth particles of dust adhere to them. After the

Water

rain becomes mixed with the soil, the number of bacteria present is very large.

Foods become contaminated with bacteria in a variety of ways. Vegetables always have the soil bacteria on their surface. Meats if exposed to the air take up bacteria from the dust. The surfaces of fruits become contaminated with bacteria in the same way. In order to diminish the contamination of foods as much as possible, ordinances are in force in many cities that require meats, fruits, candies, etc., to be covered with glass when displayed for sale.

Function of bacteria.

With bacteria so widely distributed on the earth, the question arises as to their use or function in the world. We are accustomed to think of bacteria solely as the cause of disease, and offhand we would say that this was their chief function. This is not true by any means, for instead of being harmful to life they are very beneficial; in fact, life could not be maintained without them. The causation of disease is a function limited to a small group of micro-organisms, and is of lesser importance. The much more important use of bacteria relates to their ability to produce substances called ferments or enzymes, which have the property of reducing complex organic compounds into simpler compounds and chemical elements.

The plants which form the food of animals would soon be exhausted unless they could obtain proper nutriment to sustain life and reproduce their kind. They live mainly upon carbon and nitrogen in the form of nitrates, which would soon be consumed from the

soil unless the supply was continually replenished. Now, the source of carbon and nitrogen is the excretions and secretions of animals, which contain these elements in combination with other elements. By the action of bacteria the complex animal matter is decomposed into the chemical elements that compose it. In this way the plants derive their carbon and nitrogen from the soil. Within the body the bacteria carry on much the same activities. The digestion and absorption in the intestine is dependent to a large extent on the breaking-down action of bacteria. We cannot absorb meat and vegetable as such, and it is only after our food has been separated into simple compounds and elements that it is absorbed to nourish the body. In this process the bacteria play no small part. But bacteria are not only agents capable of breaking down complex substances; they also build up substances from chemical elements. Some plants take their nitrogen from the air, but they would not be able to do so were it not for the presence of certain bacteria growing in the roots.

The maintenance of life in the world is often described as a cycle; first, the chemical elements are built up into plants, the plants nourish the animals, then the animal tissue is consumed and excreted to be broken down into elements. In each step the bacteria play a most important part.

Commercial use of bacteria

These activities of bacteria and their enzymes are made use of commercially; the fermenting action on sugars converting them into alcohol is used in making

beer and wine, the clotting of milk by bacteria in making cheese, the fermenting of cabbage in making sauerkraut.

Ptomaines

It may be well to mention here certain substances that are formed principally in the decomposition of meat and fish by bacteria. They are called ptomaines, and are present in partially decomposed animal and vegetable matter. Some of them are highly poisonous. The most common poisonous ptomaines are those found in partially decomposed meat, fish, and ice-cream.

CHAPTER III.

THE DESTRUCTION OF BACTERIA, STERILIZATION AND DISINFECTION.

Definition of disinfection

THE knowledge of the means by which bacteria are destroyed underlies the methods employed in disinfection, sterilization, and antisepsis as they are used in preventing the spread of infection. The term disinfection means the total destruction of bacteria by any agent, while sterilization is limited to the destruction of bacteria by heat. An antiseptic is a chemical agent that prevents the growth and multiplication of bacteria, but does not necessarily destroy them. A deodorant is a substance that masks offensive odors or substitutes an agreeable odor for a disagreeable one. Some of the disinfectants and antiseptics are also deodorants, but few of the deodorants have disinfectant properties.

Sterilization and antisepsis

Physical agents

The agents that affect bacteria injuriously may be physical or chemical. Among the physical agents may be mentioned drying, light, and heat.

Drying

Drying prevents the growth of bacteria and will eventually destroy them. The spores of bacteria, however, will resist drying for a much longer time. It is for this reason that the bacterial content of dust is chiefly in the form of spores. The effect of drying is influenced by the temperature at which the drying

takes place, being much more injurious at high than at low temperature.

Sunlight

Sunlight is a very powerful and effective agent for destroying bacteria. By experiment it has been proven that the tubercle bacillus, the cause of consumption, is killed by sunlight in two hours or less, depending upon the thickness of the material surrounding it. The effect of electric light and the X-ray is very much less powerful than sunlight, and to be effective must be concentrated and allowed to act for a greater length of time.

Heat

Heat is the most powerful of all the physical agents. Its destructive action is dependent upon the degree of temperature and the length of time it is applied; the higher the temperature, the less the time required. It may be employed either as dry or moist heat. Dry heat is used in the sterilization of glassware, such as flasks, test-tubes, swabs, and pipettes. The temperature should reach 140° to 150° C., and must be allowed to act for one hour in order to effect sterilization. The instrument used for this purpose is called a dry-heat sterilizer, and consists of a double-walled box made of sheet iron and asbestos. An opening in the top admits a thermometer by which the temperature of the inner chamber may be measured. The flame, usually a triple Bunsen burner, generates the heat underneath, which circulates between the walls of the box, keeping the temperature even on all sides.

For sterilizing all sorts of surgical instruments, except those with cutting edge, moist heat is used. It

is more effective than dry heat, because it has greater penetration. Boiling for five minutes will destroy all forms of bacteria except spores, which require boiling for two hours. The destructive action is intensified and the danger of rusting avoided if sodium carbonate

Boiling

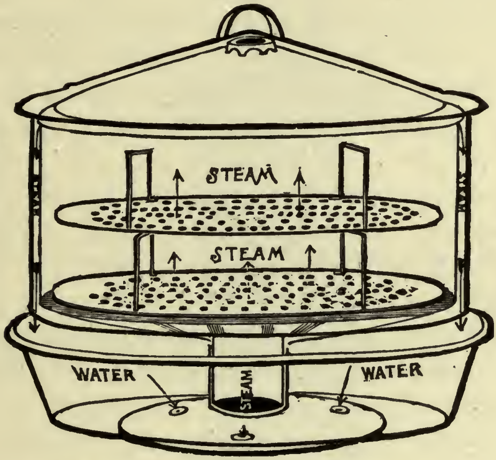

Fig. 2.—Arnold's steam sterilizer.

is added to the water in amount sufficient to make a 1 per cent. solution. Live steam is employed for sterilizing dressings. The instrument most often used is the Arnold sterilizer, which consists of two metal chambers, one within the other, beneath which is a pan containing the water to be heated. A flame underneath boils the water and generates the steam, which rises to the upper chamber and penetrates the contents. The exposure of dressings in this way to live steam

Steam

Fractional sterilization

will kill bacteria in thirty minutes, but not their spores. In order to destroy the spores fractional sterilization is employed. This is done by sterilizing for thirty minutes on three successive days. By the first exposure the bacteria are killed, but the spores that may be present are not. The dressings are now allowed to stand for twenty-four hours at room temperature in order to allow the spores to develop into bacteria, when another exposure of thirty minutes is made. This is repeated at the end of another twenty-four hours. At the end of the third exposure it is presumed that all spores have developed into bacteria, and that all bacteria have been destroyed by steam. Live steam is also used for killing bacteria in milk, and will be considered later.

Sterilization by steam under pressure

By far the most effective method of sterilizing by heat is the use of steam under pressure. The action of the steam is intensified and its penetrating power increased by the pressure. The instrument used is called an autoclave. It consists of a double-walled cylinder or globe made of metal, with a steam gauge and vent at the top. The materials to be sterilized are placed in the inner chamber, the door closed, and the steam allowed to enter the outer jacket. The vent at the top is left open until the steam has forced out all the air, as air interferes with the action of the steam. After closing the vent the steam is forced into the inner jacket until the gauge shows a pressure of 15 pounds, or one atmosphere, and allowed to remain so for fifteen to twenty minutes. This exposure will kill all

bacteria and spores. If any fluid contained in flasks or test-tubes is being sterilized, care must be taken that the steam be allowed to escape gradually at the end of the exposure, otherwise the suction will draw the plugs

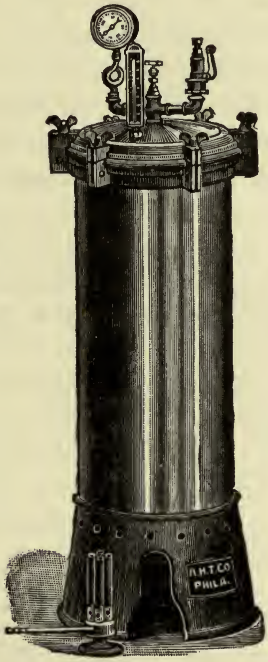

Fig. 3.—Autoclave. (A. H. T. Co.)

from them. Much larger sterilizers which embody the same principles as the one just described are used by hospitals, quarantine stations, and departments of health in cities for disinfecting wearing apparel, bed-clothing, and bedding.

Chemical agents

The number of chemical agents having destructive action on bacteria is very large, and no attempt will be made to speak of them all. It will suffice to mention a few of the most common ones, and describe the way they may be applied best. Chemical disinfectants may be used dry, in solution, or in the form of gas.

Dry disinfection

As examples of dry disinfectants, boric acid, bismuth, and iodoform may be mentioned. All are used in concentrated form as they are obtained commercially. Boric acid and bismuth are weakly bactericidal, and have an antiseptic rather than a disinfectant action. Iodoform when iodine is set free is disinfectant. Their chief use is on infected wounds.

Some of the most used disinfectant solutions are as follows:—

Disinfectant solutions

Formalin (a 40% solution of formaldehyde gas in water)	10 to 20 %.
Bichloride of mercury	1 : 500 to 1 : 1000.
Carbolic acid	5%.
Chlorinated lime (chloride of lime)	5% (6 oz. to gal.).
Hydrogen peroxide	20%.
Alcohol	70%.

Not all of these solutions are equally efficacious for disinfecting, and each one has its advantages and disadvantages.

Formalin is an excellent disinfectant, and, in addition, is also a good deodorant. It does not injure fabrics, is not poisonous, and does not coagulate albu-

min. It is liable to rust iron and steel. It is suitable for the disinfection of urine, sputum, feces, and albuminous discharges. It is not a good skin disinfectant because it hardens the skin and in some cases will cause a dermatitis.

Bichloride of mercury is of limited usefulness because it is a corrosive poison, corrodes all metals, and coagulates albumin. This last action renders it of little use for the disinfection of sputum, feces, or pus. On the other hand, it is excellent for disinfecting floors, walls, and furniture; that is, surface disinfection. In the strength of 1 : 1000 it kills bacteria in a half an hour, but for spores a 1 : 500 solution must be used. It is widely used for skin disinfection; for this purpose a 1 : 1000 solution is sufficiently strong. On account of the poisonous property of bichloride solutions it is safer to add coloring material to prevent any possibility of their being drunk by mistake.

Carbolic acid is suitable for the disinfection of intestinal discharges, sputum, urine, floors, furniture, soiled linen, and clothing. It will coagulate albumin, but its action is not interfered with to so great an extent as is the case with bichloride of mercury. Cresols, chemical substances closely related to carbolic acid, are more powerful and not so poisonous. They may be used in 5 per cent. solution.

Chlorinated lime is a deodorant as well as a disinfectant, both properties being dependent upon the liberation of chlorine gas in the presence of moisture. It is most widely known and used for the disinfec-

tion of intestinal discharges of typhoid-fever patients. It undergoes decomposition readily; so care must be taken that it be fresh if good results are expected. For disinfecting stools the amount of lime solution should be much in excess of the volume of the stool, and it should be allowed to act for several hours. It can be used also for disinfecting floors and woodwork, but should not be used on colored fabrics, as it is a powerful bleacher.

Hydrogen peroxide decomposes readily, giving off free oxygen, upon which its disinfecting action depends. It is used to a large extent for destroying the pus bacteria of superficial wounds, and is an excellent mouth disinfectant.

Alcohol, either absolute or in 95 per cent. strength, is weakly disinfectant. The addition of water seems to add to its disinfecting action. Solutions of 50 to 70 per cent. are best. The use of alcohol is limited. Perhaps its greatest usefulness is in destroying bacteria in the skin, although even for this it is rarely depended upon alone.

Disinfectant gases

Of the disinfectant gases only the two most often used need be mentioned: Sulphur-dioxide gas is made by burning roll sulphur in the presence of water vapor. The vapor is essential because the disinfectant action depends upon the formation of sulphurous acid, which is made by the combination of the water vapor with the fumes of sulphur. It requires about 8 pounds of sulphur for every 3000 cubic feet of air space, and it should be allowed to act for at least twenty-four hours.

It is a surface disinfectant having very little penetrating power, and is not as reliable as it was once thought to be. It is liable to corrode fabrics and destroy colors. It tarnishes metals and leaves a disagreeable odor for some time after it is used.

Formaldehyde gas is made in a variety of ways. For use in hospitals and by boards of health an autoclave is used, which generates the gas under pressure. After the room has been sealed to prevent the gas from escaping, the gas from the autoclave is forced into the room through the keyhole of the door. A much simpler way that is practical for home disinfection is the burning of paraform candles in the presence of moisture. The disinfectant action is strongest when the temperature of the room is between 90° and 100° F. The gas is a surface disinfectant; consequently, articles to be disinfected should be hung up or so arranged as to allow the free circulation of the gas about them. It is the most efficient disinfectant known when properly used, and is also a deodorant. It has no harmful action on clothing or other household goods. The vapor is very irritating to the eyes and upper air-passages. Although the gas is very destructive to bacteria and their spores, it will not kill vermin.

Disinfection of excretions

In disinfecting during or after illness of contagious or infectious nature, it is necessary to render all discharges, excreta, and so on, non-infectious and, at the conclusion of the illness, to render the apartment in which the patient has been sick safe for others

to occupy. In practical disinfection the choice of the disinfectant should be governed by the source and character of the material to be disinfected, and by the expense, the ease, and the thoroughness with which the disinfectant may be applied.

Sputum

Sputum always contains a large proportion of mucus, in which the bacteria are imbedded. In order to destroy these bacteria, chemical agents of considerable penetrating power are required, and should be allowed to act for considerable periods of time. The two that best meet these requirements are formalin, 10 per cent. solution, and carbolic acid in 5 per cent. strength. A much safer way is to collect all sputum in paper sputum-cups or paper napkins and then burn them. This way has been in use a long time for the disposal of tuberculous sputum, but it is equally as practical for the mouth and nasal discharges of diphtheria, tonsillitis, pneumonia, and cerebrospinal meningitis.

Feces

Feces can be quickly and thoroughly destroyed by burning them or mixing them with boiling water. If chemical disinfectants are employed, formalin (10 per cent.) or carbolic acid (5 per cent.) may be used. The amount of either of these solutions should be twice that of the stool. Chlorinated lime, so long used for stool disinfection, has no advantages over formalin or carbolic acid, and is not so easy to use. The urine may be disinfected in the same manner as the stools.

Clothing, towels, napkins, and bedding should be soaked for one-half hour in a 5 per cent. solution of

carbolic acid before leaving the sickroom to be laundered. Dishes, knives, forks, etc., should be immersed in 5 per cent. carbolic solution and then boiled. It seems hardly necessary to say that one set of dishes should be kept in the sickroom for the exclusive use of the patient, and cleaned there. Clothing

Apartments Apartments occupied by persons sick with contagious or infectious disease should not be occupied again until the room and its contents have been thoroughly disinfected. In order to simplify this procedure a little forethought on the part of the nurse, in removing from the sickroom all articles not to be used, will assist a great deal. Carpets, upholstered furniture, hangings, pictures, and bric-a-brac can easily be spared from the room. At the conclusion of the illness by far the most effective means of rendering the room free from infection is a thorough scrubbing of everything washable with soap and hot water, a continued exposure of the room to fresh air and sunlight, and the burning of everything that cannot be washed or is of small value. The effect of the scrubbing is increased if followed by a solution of carbolic acid or bichloride solution. If arrangements cannot be made to have the mattress sterilized by steam under pressure it is safer to burn it.

If the disinfection of the apartments by gas, either formaldehyde or sulphur, is to be employed, it should follow the cleansing of the room after the manner described above. The room must first of all be sealed to prevent the gas from escaping. This can

be done by plugging with cotton all crevices about the windows and doors, and pasting paper over radiators and ventilators.

Not much dependence should be placed on gas disinfection alone. It should be clearly understood that a thorough application of soap and water and free exposure to fresh air and sunlight are much to be preferred to the simple introduction of formalin gas or any other disinfectant without due regard to the proper disposition of the room contents, temperature, time of exposure, and the quantity of the disinfectant used. The careless use of gas disinfection and the popular belief that filling a room with gas kills all contagion have led to disastrous consequences, and are responsible for the disrepute into which disinfection has fallen in some quarters.

CHAPTER IV.

INFECTION AND IMMUNITY.

Patho-genic and non-patho-genic bac-teria

In the preceding chapters we have been dealing with the subject of bacteriology in the broadest sense. Attention has been directed to the function of bacteria in the life of the world, to their appearance, their manner of growth, and the means employed for their destruction. As physicians and nurses our interest centers about a very small part of the bacterial kingdom, the one having to do with the production of disease. Bacteria that produce disease are termed pathogenic, while those varieties that do not are called non-pathogenic. By far the larger number of pathogenic bacteria thrive only in the living tissues of animals. These are called parasites. Some kinds of bacteria thrive only on dead tissues or wounded surfaces and, by decomposing them, form poisons (ptomaines) which may be absorbed and give rise to symptoms such as fever, chills, and headache. These are termed saprophytes. When pathogenic bacteria gain access to the tissues and produce injury and symptoms, we say that infection has taken place.

Infection defined

Infec-tious and con-tagious

Here it may be well to say a word as to the meaning of the terms "infectious" and "contagious." They have been used somewhat loosely and have led to a great deal of confusion. Any disease that is caused by the entrance into the body of a living micro-

organism is called infectious. As examples of infectious disease, diphtheria, pneumonia, influenza, tuberculosis, and syphilis may be mentioned; although there are many others. A contagious disease is one that is transmitted from one person to another through the air or by simply coming into the presence of or touching the sick. Smallpox, scarlet fever, measles, chickenpox, and German measles are contagious. All contagious diseases are infectious, but not all infectious diseases are contagious. Diseases like cholera, glanders, pneumonia, plague, tuberculosis, and syphilis cannot be transmitted through the air or by coming into the presence of the sick. Typhoid fever may be considered infectious through water and other infected foods, and contagious by contact with the so-called typhoid carriers.

The terms "infestation" or "infestion" are applied to diseases caused by the entrance into the body of large parasites such as amebæ, worms, and so on.

Factors influencing infection

While the presence of pathogenic bacteria is necessary to cause infection, other factors of much importance must be taken into consideration. This must be so, as every-day experience shows. In any epidemic of infectious disease only a portion of those exposed become infected. Even among those infected the disease presents all variations from the very mild to the most severe. The factors that influence the onset and course of infections relate both to the bacteria and the individuals exposed to them.

So far as the bacteria themselves are concerned,

infection depends in part on their power of producing disease, that is, their virulence. Conditions that are not suited to the growth of bacteria will diminish or destroy the virulence; the continued cultivation of bacteria outside the body on artificial culture media will do this. Bacteria that have lost the power of producing disease are spoken of as being attenuated. Another factor that modifies infection is the number of bacteria that invade the tissues. While the exact number of bacteria necessary to cause infection is not known, it may be said that the greater the virulence the fewer the bacteria required. The path by which bacteria enter the tissues frequently determines whether infection is caused or not. The bacilli of typhoid fever to cause infection must be swallowed, but if they are rubbed into the skin no infection results. On the other hand, the pus-forming bacteria like the staphylococci and streptococci may be swallowed without causing infection, but if they are rubbed into the skin a boil or an abscess is almost sure to result. So to cause infection bacteria must enter the body through channels best adapted to their growth and multiplication.

On the part of bacteria

Virulence

Attenuation

Avenue of infection

Concerning the individual exposed to infection it is known that everyone is endowed to a variable degree with defensive substances in the blood and tissues that tend to overcome and destroy invading bacteria. Unhealthy people, as everyone knows, are more likely to become infected and to succumb to infection than the healthy. This power of the human

On the part of the individual

organism to resist infection will be discussed more fully under the subject of immunity.

Infection from bacteria outside the body

How does infection take place? It is the result of the invasion of the body tissues by pathogenic bacteria that live either on the surface of the body or from those that live on the mucous membranes inside the body. Injuries play an important part in causing infections. Injuries caused by firearms may be the entering point of tetanus bacilli, the cause of lockjaw, while rabies or hydrophobia is spread through the bites of mad dogs. Careless manipulations with soiled catheters, speculums, syringes, and so on may cause injury to the tissues and be the means of introducing bacteria. In the case of the contagious fevers like measles, chicken-pox, whooping-cough, and scarlet fever the infecting agent seems to be in the air and causes infection by being inhaled. Bedding, clothing, and utensils that have been contaminated with infectious material may be the means of spreading infection. Finally, the bites of insects and vermin may cause infection. It is known that certain kinds of mosquitoes transmit malarial fever and yellow fever; flies may spread typhoid fever by depositing the typhoid bacilli on food materials.

Infection from bacteria living inside the body

The body may be looked upon as the host for large numbers of bacteria. At birth, however, all healthy animals are free from bacteria; but almost immediately afterward they are deposited upon the surface of the body by the dust in the air, and are introduced into the body by food and by the air

breathed. When these bacteria gain access to the body, only those survive that find the conditions favorable for their existence. For this reason it is found that each cavity or portion of the body harbors a group of bacteria peculiar to it. The varieties of bacteria found in the saliva, for example, are quite different from those found in the intestine. Most of these constant bacteria of the body are harmless, but some pathogenic forms occur which manifest their power to produce disease only when some injury affords a point of entrance to the tissues or the resistance of the individual is lowered. Thus in the skin there may be many kinds of bacteria, the most important of which are the pus-forming cocci, the staphylococci, and streptococci. They do no harm under normal conditions, but if there is any injury to the skin these organisms may enter and give rise to a boil, an abscess, or erysipelas. It is mainly against these pus-forming bacteria that the preparation of the patient before operation is directed. Unfortunately these bacteria live actually in the skin, that is, below the surface; so that skin disinfection must be very thorough to be effectual and, even under most favorable conditions, cannot be considered as absolute.

In the air-passages large numbers of bacteria are found which enter with the air breathed in. Most of them are caught on the moist surfaces of the mouth, throat, and nose; very few if any ever reach the lungs directly through the trachea and bronchi. In the mouth the pneumococci, staphylococci, and strepto-

cocci are frequently present, but do no harm unless the vitality is lowered. The stomach is generally free from bacteria, due to the acid in its secretions. If however there is any disturbance of digestion and the secretions are no longer acid, the bacteria swallowed in the food may cause fermentation and other disorders. The intestine harbors great numbers of bacteria, chiefly the colon bacillus and others closely allied to it. They are, in health, not only harmless, but of much benefit in breaking down the food into substances that can be absorbed for nutriment of the tissues. Under conditions of lowered resistance or when injury to the intestines has been done, they may cause infection.

After infection has taken place it may remain localized in the form of a boil or abscess, or it may spread so that the blood contains the infecting organism. When infections become generalized the condition is called septicemia, and when there is added to this scattered areas of pus formation throughout the body the condition is called pyemia. Toxemia is the condition caused by the poisons of bacteria, either in local or general infections.

How do bacteria produce injury to the tissues? In two ways: The multiplication of bacteria in the tissues may cause injury in a mechanical way by obstructing the very small blood-vessels, causing the necrosis or death of the tissue. The absorption of the necrotic material gives rise to the symptoms of infection. Much greater injury is produced by the absorp-

tion of the poisons or toxins made by the bacteria. These poisons may be extracellular or intracellular. The extracellular toxins are thrown out of the bodies of the bacteria into the tissues or media in which they are growing. The word toxin when used alone is taken to mean an extracellular toxin. The intracellular or endotoxins are retained within the bodies of the bacteria and are set free only after their death or dissolution. After absorption the bacterial toxins do not affect all organs or tissues equally, but exhibit a selective action, some attacking the red blood-corpuscles and dissolving them, others the tissues of the brain and nervous system.

Toxins, extra- and intra-cellular

One might think, from what has been said, that men and animals are wholly at the mercy of bacteria. Fortunately this is not so, as all are endowed with certain defensive powers that resist the injurious action of bacteria and their poisons. This resistance to disease is called immunity.

Immunity

Many of the diseases that are infectious in man cannot be transmitted to animals and, conversely, some of the infectious diseases of animals do not occur in man.

Natural immunity

Among the races of men variations in the resistance to disease is observed; for example, the negro seems to possess a much greater resistance to infection with yellow fever than the white man. In addition to the variations in resistance among the races of man there are also variations among individuals. The conditions under which people live have much to do

Racial immunity

with their resistance. Unsanitary homes and workshops, fatigue, exposure, poor nourishment, and injuries all tend to lower the resistance to disease. The excessive or continued use of alcohol is a very important factor in lowering resistance, as is shown by the frequency of infectious disease, particularly pneumonia and tuberculosis, among drinkers. Constitutional diseases like diabetes and nephritis also lower the resistance.

Acquired immunity

It is possible to acquire immunity. Following an attack of infectious disease there commonly results an immunity that protects the individual from a second attack. The resistance gained in this way is spoken of as acquired immunity and follows diseases such as measles, mumps, scarlet fever, and typhoid fever. The duration of acquired immunity varies; after scarlet fever it oftentimes lasts during life, while after typhoid fever it may last only a year or two. That immunity could be acquired in this way was known many years ago, and led to the conception of producing immunity artificially without actually causing the individual to pass through the dangers of disease. Although not the first to attempt to produce immunity artificially, the experiments of Jenner, who discovered the protective effects of vaccination, were the most successful. The events leading up to Jenner's discovery are interesting. In England, where smallpox had been a scourge for many years, it was observed that people who had been accidentally infected with cow-pox, a modified form of smallpox in cattle, were not attacked

by smallpox even though they were exposed to it. Jenner reasoned that if an accidental infection with cow-pox could prevent against smallpox it would be a rational procedure to purposely infect with cow-pox. So, acting on the advice of his patron, Dr. John Hunter, he inoculated a boy with pus from a cow-pox pustule in May, 1796, and two months later injected the pus from a smallpox pustule without producing any disease.

Active immunity

When immunity is acquired by introducing into the body the infectious agents in modified form or in small amount, it is spoken of as active immunity because the body tissues take an active part in forming the substances that give protection. Our knowledge of how immunity is produced in this way is due principally to Pasteur, who found that the bacteria producing cholera among fowls became much less virulent after being cultivated for long periods of time on artificial culture media or after cultivation at increased temperatures. By injecting gradually increasing amounts of these attenuated bacteria of chicken-cholera into fowls he was able to immunize them to the disease.

Vaccines

The introduction of dead bacteria or vaccines in increasing doses is often used to develop immunity against those bacteria whose poisons are intracellular. This method has been practised a great deal these last few years, and has been attended with considerable success in some infections. Its most successful appli-

cation has been in the preventive inoculation against typhoid fever in the army.

Passive immunity

There is another type of immunity that can be conferred without the body tissues taking any active part in the process. For this reason it is called passive immunity. In 1890 von Behring discovered that the blood-serum of animals that had been immunized to the poisons of diphtheria and tetanus, if injected into other animals, would protect them also. Quite recently Dr. Flexner, at the Rockefeller Institute in New York, made similar observations in connection with the poison of the meningococcus, the organism causing the epidemic form of cerebrospinal meningitis.

Perhaps a brief description of the way diphtheria antitoxin is made will make this type of immunity better understoood. The animal used in the commercial preparation of diphtheria antitoxin is the horse. At the start the animal is inoculated with a very small dose of the diphtheria toxin obtained by growing the diphtheria bacillus on large flasks of bouillon. The bacilli are filtered out and the filtrate containing the soluble diphtheria toxin is used for injecting. The effect of the first injection is to make the horse sick, but not fatally so. At the end of a week a second injection is made with the same dose, but the animal is now able to stand the poison without ill effect. Each week the dose is increased until at the end of two or three months the animal is able to withstand enormous doses of the poison without ill effect, due to the protective substances formed in its body.

In other words, active immunity has been established in the horse. At the end of three or four months the animal is bled to the amount of five or six quarts, and the blood is set aside to clot. In the serum that separates from the clot are the same substances that protected the horse from the diphtheria poison. This is the diphtheria antitoxin. It is standardized by determining the smallest amount of antitoxin that will neutralize 100 times the fatal dose of toxin for a guinea-pig weighing 250 grams. This amount is called the antitoxin unit, and enables us to measure the dose of antitoxin.

What the nature of these substances is that enables us to resist infection is not known, and the way in which they act is built up on theory that is complicated and difficult to understand. It is sufficient for us to know that soon after infection occurs the body tissues and fluids begin to protect themselves against the invading bacteria and their poisons. The first defense is made by the white blood-corpuscles, or leucocytes, the scavenger cells of the blood. They are attracted in great number to the point of infection and destroy the invading bacteria by taking them into their cell bodies and digesting them. The fate of infections depends many times on the defense of the phagocytes; if they are sufficient for the needs of the occasion, the infection is checked and localized; if they are not, the infection extends and may become general.

Phagocytosis

The body, however, does not rely entirely on the phagocytes for protection. Infection stimulates the

Bacteriolysins

tissues to form substances, circulating in the blood-serum, which combine with and neutralize the poisons of bacteria. They are spoken of as antibodies and act in different ways; some, called bacteriolysins, dissolve the bacterial cells; others gather the bacteria into clumps or clusters; these are called agglutinins; and finally substances may be formed that act on the bacteria in such a way as to make them more readily digested by the phagocytes; these are called opsonins.

Agglutinins

Opsonins

It is an interesting fact, and one of much importance, that the amount of these protective substances formed is not only sufficient to render an infection harmless, but is greatly in excess of the needs of the moment. They remain stored away in the tissues ready to be utilized when the same infective agent again attacks; this is the way that immunity is established.

Anaphylaxis

The word anaphylaxis, literally translated from the Greek, means against protection, the exact opposite of prophylaxis, which means for protection. This name has been given to a condition of hypersensitiveness which has been found to exist in certain animals and man. For example, it has been shown that guinea-pigs may be made sensitive to harmless proteids like egg-albumin or milk. The first injection causes no symptoms, but the second, even when the dose is smaller, may cause shortness of breath, spasms, and death. It requires from ten to fourteen days after the first injection for this hypersensitiveness to develop.

A similar hypersensitiveness has been observed in some human beings to the horse serum in diphtheria antitoxin, and the symptoms of serum sickness have been attributed to it (see Diphtheria). The reactions following the use of tuberculin and mallein are also believed to be due to anaphylaxis.

CHAPTER V.

THE GROUP OF PYOGENIC COCCI.

In the following chapters the characteristics of the individual species of bacteria associated with the production of disease will be considered. Inasmuch as certain ones are closely related in their growth, morphology, and manner of producing infection, it is convenient to form them into groups; thus there is the group of pyogenic cocci (pus-forming cocci) and the intestinal group, which may also be subdivided into the typhoid and dysentery groups. On account of their wide distribution and the frequency with which they cause infection, the pyogenic group will be considered first.

Staphylococcus pyogenes

The coccus that most commonly causes infection is the staphylococcus, so named because of its characteristic arrangement into clusters often likened to bunches of grapes. (See Fig. 1, *A*, page 7.) Several varieties are distinguished by the pigment they produce when grown in cultures. The *Staphylococus aureus* produces a golden-yellow pigment, the *S. citreus* a lemon-yellow pigment, while the *S. albus* grows without forming any color. The *Staphylococcus epidermidis albus* is a variety found in the under layers of the skin. The size of these coccus forms differ, some being larger than others. They do not form spores, and all are without motility.

The *aureus* is the most virulent of all staphylococci. The infections caused by the staphylococci vary with the virulence of the organism and the resistance of the individual infected. The infection may be local like a boil or an abscess, or it may extend to involve large areas of tissue (cellulitis).

General infections, septicemia, and pyemia are very often caused by these organisms. Malignant endocarditis and puerperal fever come under this head. They are usually the cause of infection in wounds, although there are other bacteria that may do this. It is to remove all bacteria, especially the pus-cocci coming in contact with the patient, that the precautions or technique of the operating-room is directed. Since the pus-cocci are so often found on the skin, careful washing and scrubbing of the hands followed by a disinfectant is employed to destroy them. It is important to remember that these precautions cannot be safely performed in a careless manner, as the pyogenic cocci may be located in rather than on the skin. They are to some degree resistant to disinfectants, and require an exposure of at least ten minutes in a 1 : 1000 solution of bichloride of mercury.

The injury caused in infections by the staphylococci is due almost wholly to the toxins in part set free and in part retained in their cell bodies, and liberated in the dissolution after death. The toxins cause the formation of pus and also attack the red blood-cells, dissolving them. This explains the anemia that always accompanies these infections.

Strepto-coccus pyogenes

The streptococcus is one of the pus-forming cocci that is characterized by multiplication in one plane, producing strings or chains of cocci. (See Fig. 1, *A*, 3, page 7.) There are numerous varieties of streptococci that differ in size, shape, and virulence. They may be found in water, milk, dust, and discharges from the intestinal tract. In general they are more resistant to harmful influences than the staphylococci, and more virulent; consequently infections due to them are more serious and attended with a higher mortality rate. The toxic symptoms, fever, rigors, sweats, and so on, are more pronounced.

Infections with the streptococcus may be localized as in the case of boils, abscesses, and carbuncles; but because of the greater virulence, they are liable to cause edema and to extend along the lymphatic vessels to involve the adjacent lymphatic glands. In the lungs the streptococcus frequently causes pneumonia and empyema; in the throat, tonsillitis with the formation of a membrane often identical with that seen in diphtheria, and, in the skin, erysipelas. It is often the infecting agent in disease of the bones, osteomyelitis, and in the general infections such as endocarditis and puerperal fever. In association with other bacteria they gave rise to what are called mixed infections.

Micro-coccus tetrage-nus

The *Micrococcus tetragenus* is a pus-forming organism of low-grade virulence. Its arrangement is peculiar, forming squares of four cocci. It is found frequently in the sputum and causes infection usually in combination with some other micro-organism.

The gonococcus

The gonococcus is the organism causing gonorrhea. It is a diplococcus, always occurring in pairs with the surfaces facing one another flattened like two coffee-beans. In pus it is found almost always within the bodies of the leucocytes. It is very difficult to

Fig. 4.—Gonorrheal pus, showing gonococci within a leucocyte.

cultivate, as it does not grow on the ordinary culture media. By the diplococcus form, coffee-bean shape, and situation within the leucocytes, it is identified by direct microscopic examination of pus.

Infection with the gonococcus, or gonorrhea, is classed as a venereal disease because it is commonly confined to the genital organs. It is an exceedingly common disease, and is spread almost always by

sexual contact. In the male the infection starts, after an incubation period of five to seven days, with a discharge of pus from the urethra. The acute stage lasts usually from three to six weeks, and then recedes either entirely or leaves a catarrhal inflammation which may last and be infectious for an indefinite period. In approximately half of the cases, however, the infection extends back to involve the bladder, prostate gland, or seminal vesicles. When this happens the gonococci become buried in the tissues and frequently remain dormant for years, only to light up again when conditions favor it. Infection of these organs is most difficult to eradicate, and a person so infected may be able to transmit the disease to others over long periods of time. It is a frequent cause of sterility in the male.

In the female the infection likewise starts in the urethra, but very soon spreads to the glands of Bartholin situated beneath the floor of the vagina. Later it may extend to the cervix of the uterus, thence to the mucous lining, to involve finally the Fallopian tubes. It has been recognized for years that gonorrheal infections are responsible for the great majority of inflammations of the uterus and Fallopian tubes that require surgical intervention. The disease is harder to combat in the female than in the male, partly because the acute symptoms are not so marked, and so the nature of the infection may escape detection, and partly because the anatomy of the organs infected is such that it is next to impossible to

treat the infection thoroughly. The period over which the disease may continue infectious in the female may be years, and if the tubes and ovaries are involved sterility usually ensues.

Ophthalmia neonatorum

Gonorrheal infection of the eyes is fairly common. It occurs in the newborn most often, and is called ophthalmia neonatorum. Ulcers on the cornea which interfere with vision in later life, or complete destruction of the eyeball, may result. It is the chief cause of blindness in children. The infection gets into the eyes during delivery, and as a prophylactic measure it is advisable to instil a drop or two of 1 per cent. nitrate of silver into the eyes immediately after birth. In adults the infection is usually introduced by infected fingers, handkerchiefs, or towels.

Vaginitis

Among children in institutions gonorrheal infection of the vagina, vaginitis, occurs in epidemic form. It spreads from child to child with great rapidity, and is very difficult to check. The infection starts from one child so infected, and is spread by napkins, towels, or directly from one child to another.

While infections with the gonococcus are generally localized, they may in rare instances become general, causing arthritis, endocarditis, and meningitis. The toxin of the gonococcus is within the body of the organism, and is liberated only after death of the cell body. Dead cultures of gonococci, or vaccines, have been employed in the treatment of the infection, but have proven only partially successful in the complications such as arthritis, epididymitis,

orchitis, and the vaginitis of children. Serum obtained from animals that have been immunized with living cultures of gonococci (active immunization) has also been only partly successful, probably because there seems to be a great many different strains or families of gonococci.

The pneumococcus

Pneumonia is an acute infectious disease caused by a variety of micro-organisms, the chief one being the *Diplococcus pneumoniæ,* or the pneumococcus. Other bacteria, such as the streptococcus, staphylococcus, the influenza and typhoid bacillus, may also cause pneumonia.

Morphology

The pneumococcus is a small, lance-shaped organism, usually arranged in pairs, and these pairs may form chains not unlike the streptococcus in appearance. About each pair there may be seen in suitable preparations a capsule with a clear zone between it and the body of the organism. The capsule is seen best in smears of the fresh sputum from pneumonia patients, and is of considerable importance in identifying the organism.

Pneumococci are present in the mouth and throat of most persons in health, and cause no injury or infection unless the resistance of the individual is lowered. Some of the factors that lower the resistance are: exposure, alcoholism, debilitating and wasting diseases, unhealthy surroundings, and other infectious diseases, particularly scarlet fever and measles. When the resistance has been lowered the pneumococci in the mouth or throat may gain en-

trance to the lungs by way of the circulating blood. Infection of the lungs by direct invasion through the respiratory tract is improbable. The popular idea that pneumonia is the direct result of taking cold is

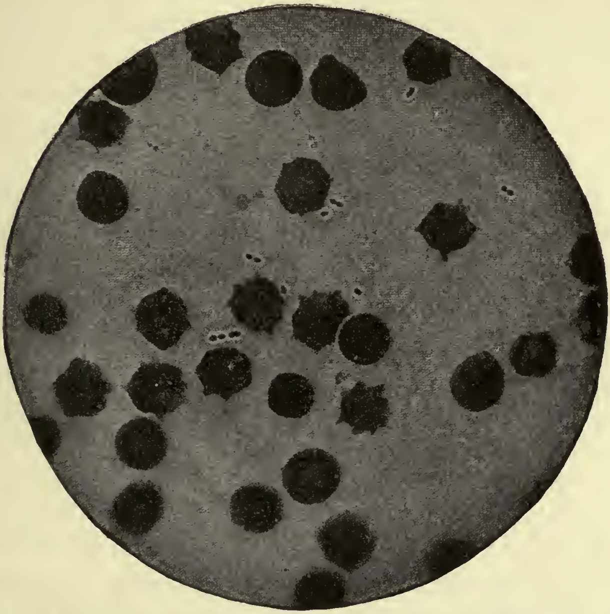

Fig. 5.—Diplococcus pneumoniæ in the heart's blood of a rabbit. × 1000. (After *Fränkel-Pfeiffer.*)

erroneous. While it is true that exposure to cold may so lower the resistance as to favor the infection of the lungs, pneumonia rarely follows a simple cold. The infection in pneumonia is general, that is, a septicemia in which the manifestations are localized

4

chiefly in the lungs. With this conception of the disease in mind, it is easy to understand how the complications such as otitis media (a suppuration of the middle ear) and meningitis may occur.

That pneumonia may be communicated from one person to another is proved by the outbreaks of the disease in epidemic form in crowded buildings such as barracks and hospitals. It is not spread by direct contact, however, as frequently as are many of the other infectious diseases. During the course of pneumonia the pneumococcus is present in large numbers in the sputum and, as the pneumonic sputum is usually tenacious and difficult to expel, the hands and bed-linen are frequently contaminated by it. By coughing and sneezing the virus may be scattered about the sickroom and hospital ward, and in this way become a part of the dust. Precautions therefore should be taken to collect all sputum in paper boxes or napkins and to burn it. The hands of the patient should be kept clean with disinfectant (bichloride of mercury 1 : 1000), and any contamination of the clothing should be disinfected promptly. It is advisable for attendants on pneumonia patients to disinfect the hands after handling the patient. Rooms and apartments that have been occupied by pneumonia patients should be disinfected at the termination of the illness.

Precautions

Cerebrospinal meningitis is an infectious disease in which the agent of infection produces an inflammation of the covering of the brain and spinal cord.

The infection may be caused by any one of a number of micro-organisms,—the pneumococcus, the typhoid bacillus, the influenza bacillus, the tubercle bacillus, the *Streptococcus* or *Staphylococcus pyogenes.* When the meningitis results from infection with these organisms it is generally secondary to an infection elsewhere in the body, as, for example, during pneumonia, typhoid fever, pulmonary tuberculosis, or septicemia.

The Meningococcus

The primary form of meningitis, the form that frequently occurs in epidemics and is more commonly called spotted fever, is due to infection with the meningococcus or the *Micrococcus intracellularis meningitidis,* and must not be confused with the forms mentioned above, which are always secondary.

Morphology

The meningococcus was identified and described by Professor Weichselbaum in 1887. The micro-organism was found in the cerebrospinal fluid of patients sick with the disease, and generally within the bodies of the leucocytes. For this reason the term intracellular is used in its description. The coccus occurs in pairs, a diplococcus which in appearance is not unlike the gonococcus. It can be cultivated on the ordinary laboratory media.

The presence of the disease is detected by finding the meningococcus in the cerebrospinal fluid, which is withdrawn by inserting an aspirating needle into the cerebrospinal canal, at the level of the third or fourth lumbar vertebra. This procedure is spoken of as lumbar puncture, and may be performed by physi-

cians without danger to the patient. The fluid recovered in this manner is received into sterile test-tubes, and immediately centrifuged to throw down the cellular elements contained in it. After this has been done the deposit is spread thinly on slides, appropriately stained, and examined under the microscope. The meningococcus when present is identified by its shape and arrangement in pairs, and by its location within the bodies of the leucocytes. The micro-organism may be cultivated from the spinal fluid. In addition to its use as a diagnostic aid, lumbar puncture is very often the means of relieving the symptoms of pressure due to an excessive amount of fluid in the spinal canal, and for this reason it is customary to remove a large amount of the fluid.

The meningococcus is spread by the discharges from the mouth, nose, and ears of patients sick with meningitis, and it is not infrequent to find the organisms in the secretions of the nose and mouth of those attending them. Occasionally they may be found in the nasal secretions of healthy people who may act as carriers of the infection. To prevent the disease from spreading it is essential first of all to remove the patient from contact with others, especially during the first two weeks of the disease, for at this period the infection is most virulent. Then all discharges from the mouth, nose, eyes, and ears should be collected on cloths and paper napkins and burned. Nurses in attendance should use great care to disinfect the hands after handling the patient, and spray the nose

Prevention

and mouth with antiseptic solutions. Children living in the same house should not be permitted to attend school until it is certain that they have not been infected.

Cerebrospinal meningitis in the epidemic form has been attended with a very high mortality in the past, especially among young children. In some epidemics it has been as high as 90 per cent. The treatment with antimeningitis serum, however, has been attended with success, and the excessive mortality has been considerably reduced by its use. In this country this method of treatment was begun by Dr. Flexner and Dr. Jobling at the Rockefeller Institute in New York. The serum is made by injecting horses with slowly increasing doses of meningococci that have been killed by heat. The tolerance of the animals to the poison of the meningococci is gradually increased in this way until they are able to withstand many times the fatal dose. This tolerance depends upon an active immunity due to the formation within their bodies of protective substances that neutralize the poison. After eight or twelve months the horses are bled and the blood-serum containing the protective substances is used for treating patients sick with meningitis.

Anti-meningitis serum

The extended trial of the serum in a number of epidemics has shown that, the earlier it is used after the onset of the infection, the greater its curative value. For this reason it is customary to inject the serum immediately after the withdrawal of the cere-

brospinal fluid by lumbar puncture, without waiting to determine the nature of the infecting organism. Subsequent injections are controlled by the presence or absence of the meningococcus in the cerebrospinal fluid.

CHAPTER VI.

THE BACILLI OF THE COLON, TYPHOID, DYSENTERY GROUP.

THESE organisms are usually grouped together because of the similarity in their appearance and manner of growth upon artificial culture media. All the members of this group are short, rod-shaped, often forming chains, but never forming spores. They are all motile.

The colon bacillus

Under the name of colon bacilli are grouped a number of varieties very closely related, which are usually harmless parasites living in the bodies of man and animals, but which at times become pathogenic and cause infection. The colon bacillus itself, properly called the *Bacillus coli communis,* is a constant inhabitant of the intestine in man and animals. In nature it is commonly found in soil, air, water, and milk. Just what function it performs in the intestine is not known positively, but it probably assists in breaking down food materials into simpler form so that they can be absorbed.

Once the colon bacillus has invaded the walls of the intestine, it is capable of setting up an infection. It has been found to be the cause of abscess of the liver, inflammations of the gall-bladder, the urinary bladder, the pelvis of the kidney, and the pancreas. It is frequently the cause of peritonitis in cases of rup-

tured appendix. Occasionally it causes a general infection. The poisons of the colon bacillus are contained within the body of the organism and are liberated only when it disintegrates. The knowledge of this fact has made it possible to immunize against colon infections by injecting the dead cultures, or vaccine, in slowly increasing doses. (See Immunity.)

On account of its constant presence in the intestine of man and animals, the presence of the colon bacillus in water or milk leads to the assumption that they have become infected with intestinal discharges, and so not safe for consumption. On account of the wide distribution of the colon bacillus in nature, this view has been modified to some extent, and now, unless they are present in excessive number, the water or milk is not condemned.

The Bacillus Typhosus.

The typhoid bacillus is the cause of typhoid fever. In recent years we have come to recognize that there are a number of other micro-organisms closely related to the typhoid bacillus which produce a fever and other symptoms that make a clinical picture identical with typhoid fever. It is more accurate therefore to look upon the clinical condition of typhoid as being due to any one of a group of micro-organisms the chief members of which are the typhoid, paratyphoid, and paracolon bacilli, with forms intermediate between each.

The typhoid bacillus is both a saprophyte and a parasite. As a saprophyte it is widely distributed in nature, due to its ability to adapt itself to its environment. It will live in water, ice, sewage, milk, dust, air, and soil. In surface-water typhoid bacilli will live about a week, being rapidly overgrown by other bacteria, but in distilled water they will live for three months. Freezing will kill most of them in a few days. Experiments made by placing typhoid bacilli

Fig. 6.—Typhoid bacilli showing flagella. × 1100 times. (After *Löffler.*)

in ice prove that nearly all are killed in a week, but occasionally they live for three months. The bacillus will retain life for six months in the upper layers of the soil.

Within the body they can resist the action of the gastric juice and multiply in the small intestine, where the greatest amount of damage is done. During the disease the typhoid bacilli may be found in the circulating blood, spleen, mesenteric lymphatic glands, rose-spots, and occasionally in the sputum and vomitus. Typhoid fever therefore should be considered not as a local infection of the intestine, but as a general infection with the organisms present in many

of the organs and tissues of the body. In the bile, urine, and stools the bacilli may persist for months and years after the acute infection has passed. It is for this reason that complications and sequelæ so frequently occur. The persistence of the typhoid bacilli in the bile is an important factor in the production of gall-stones; the bacilli have been found in the centers of stones from ten to fifteen years after the infection.

The typhoid bacillus is a short, rod-shaped organism with twelve or more flagella, and actively motile. It grows on all the ordinary culture media in the presence or absence of oxygen.

The way infection takes place

Infection with typhoid bacilli always occurs by way of the alimentary tract, by infected water or food. Added to the cause of infection there is usually a lowered resistance on the part of the individual.

The infection reaches the alimentary tract, most often through infected water. As we have seen, typhoid bacilli will live for months in the soil; so that the discharges from typhoid patients that have not been disinfected and are deposited in or on the ground may lead to the infection of nearby wells and streams, particularly during periods of heavy rain. Water infected in this way may give rise to local epidemics in the case of wells, or to epidemics miles away in the case of streams. The epidemic of typhoid fever in Ithaca, N. Y., in 1903 was caused by the infection of the city water-supply by a case of typhoid in a laborers' camp situated on the banks of the stream that

fed the city reservoir; 1500 cases of typhoid occurred in a remarkably short time.

Wells are sometimes infected from privies, cisterns, and open cesspools when they are placed near a well, or when the natural drainage of the soil-water is in the direction of the well. Defective walls or covering that admit surface-water render the infection of wells in this way more likely.

Milk is an excellent culture medium, and typhoid bacilli will grow readily in it. They gain entrance to the milk by washing the milk cans or pails in infected water, or from the hands of persons sick or but recently recovered from the disease. Flies may also carry the infection to milk. There have been some 185 epidemics of typhoid traced to milk. In 1903 a milkman in Boston sick with typhoid spread the disease through the milk, causing an epidemic of over 400 cases.

The infection may be spread by eating uncooked vegetables that have been washed in infected water. Oysters and clams, when they have been grown in water contaminated with sewage, have been known to carry the infection. Along the seaboard laws are now in force that prohibit the cultivation of oysters in water near the outlet of sewers. The importance of flies in the spread of typhoid has been recognized only in the last ten years. When they come in contact with typhoid patients, or with infected discharges, they carry the bacilli on their bodies and deposit them on foodstuffs.

Typhoid carriers

Finally, typhoid is spread by what are known as carriers, or persons that carry the bacilli in their bodies for a long time after they have recovered from the disease. About 4 per cent. of all typhoid cases become carriers. The bacilli may be voided in the urine or passed in the stools. Dr. Park tells of a cook who carried typhoid bacilli in the stools. During a period of five years she had been employed in six different families in which 26 cases of typhoid fever had developed, all within a month after her arrival in each family

Prevention

To limit the spread of typhoid fever, precautions should be taken to render all food materials and water free from infection and to destroy the typhoid bacilli in all discharges that may contain them. During times of epidemics special care should be taken to boil all drinking-water, to pasteurize all milk drunk, and to wash all vegetables to be eaten uncooked in boiled water.

So far as the destruction of the bacilli in the discharges is concerned, the disinfection of the urine and stools is of the utmost importance. The stools are best disinfected with a 5 per cent. solution of carbolic acid. The solid parts should be broken up with a stick that can be burned or with a glass rod that can be sterilized after using, in order that all parts of the stool may come into contact with the disinfecting fluid. Stools treated in this way should be allowed to stand for at least one hour; then thrown into the closet, buried, or burned. In the country they should be

thrown into a trench so placed that the surface drainage is away from the well or the nearest water-course. Quicklime should cover the stool in the trench and over this dirt should be thrown. The urine should be disinfected with carbolic acid solution in the same manner. All urinals and bed-pans must be disinfected with carbolic solution after being used.

The patient should have eating utensils and toilet articles for his own exclusive use, which should be marked and kept separate from all others. Remnants of food should be burned or disinfected away from the kitchen.

Nurses and attendants on typhoid patients must always wash their hands after handling the patient in a 1:1000 solution of bichloride of mercury. Uniforms and linen that have been worn in the patient's room should be soaked in carbolic solution before being taken to the laundry. Nurses should not eat in the same room with typhoid patients. The direct infection from patient to nurse is not at all uncommon, and the directions just given must be strictly observed.

After recovery the patient should be given a full bath before leaving the room, and the room itself disinfected in the usual way.

Infection with the typhoid bacillus is followed by an immunity to the disease which persists for a variable length of time, sometimes for life. Instances of reinfection are rare. The immunity is conferred by the presence in the blood of protective substances known as bacteriolysins and agglutinins. The former Immunity

are very much increased after typhoid, and by experiment it can be shown that the blood of patients after recovering from typhoid has marked power to dissolve the typhoid organisms. The agglutinins possess the power of drawing the typhoid bacilli into clusters or clumps. This phenomenon is made use of in detecting the presence of typhoid fever by what is known as the Widal reaction. It is made in this way: A small amount of blood is drawn into a capillary tube from the patient's ear and allowed to clot. By clotting the serum is separated from the blood. The object of the test is to see if the serum contains any agglutinins of typhoid bacilli. All blood contains a small amount of agglutinating substance; so the serum is diluted, say, to 1 : 50 or 1 : 100 and mixed with a fresh bouillon culture of typhoid bacilli in equal parts. The mixture is now watched under the microscope, and if the agglutinins are present the typhoid bacilli will be seen drawn together into clumps or clusters and lose their motility. When clumping is complete the reaction is said to be positive, and means that the patient now has or recently has had typhoid fever. Negative reactions are of no significance, as the reaction is not constant, being present one day and absent the next. A positive reaction, however, is conclusive.

The Widal reaction

Production of immunity by vaccines

Quite recently the prevention of typhoid has been greatly advanced by what is known as vaccination. As mentioned earlier in the chapter, the poison of the typhoid bacilli is found within the body of the cells,

and is liberated only after death and disintegration of the organisms. An active immunity to the disease can be produced by injecting the killed typhoid bacilli, which after disintegration set free their poisons in the blood and stimulate the organs and tissues of the body to form protective substances that prevent infection. This method of creating immunity to typhoid has been

Fig. 7.—Stages of the Widal reaction. (After *Robin.*)

practised a great deal in the last two years with very gratifying results. It was first tried in this country in the U. S. Army maneuver camp at San Antonio, Texas; 8097 men were vaccinated, that is, they were injected with a killed culture of typhoid bacilli on three occasions, the dose being increased each time. Only one case developed among these men, and this one was not fatal.

Among nurses and hospital attendants the anti-

typhoid vaccination is being largely practised. In the Massachusetts General Hospital 1381 nurses and attendants were vaccinated with no cases of typhoid developing subsequently.

The injections are usually made in the arm, and are followed rarely by a reaction marked by fever, headache, and malaise. This occurs in only 1 per cent. of the cases.

The Bacillus Paratyphosus.

The paratyphoid bacillus in shape and size is very much like the typhoid bacillus. It is differentiated from the typhoid bacillus by its ability to ferment glucose. There are two types of paratyphoid bacilli, called type A and B, which differ slightly in their method of growth. They also behave differently in the agglutination or Widal reaction. The blood of patients sick with paratyphoid fever will not agglutinate the typhoid bacillus. If the infection is due to paratyphoid A the blood will not agglutinate the paratyphoid B, but only the A.

The agglutination reaction is a very good way to diagnose the type of infection present in all cases of typhoid-like infection.

The course of the fever in paratyphoid infections is somewhat milder and shorter than in typhoid. In the fatal cases coming to autopsy the spleen and mesenteric glands are enlarged just as in typhoid, but the intestines show little change. Changes in the

bowel do occur because hemorrhage sometimes occurs in paratyphoid fever.

Immunity follows an attack of paratyphoid fever just as in true typhoid, but the protection is only against the type of paratyphoid bacillus causing the infection. A case illustrating this point came under the writer's observation in the summer of 1913, in which the patient developed typhoid-like symptoms and fever, although he had had a severe typhoid infection only a few years before. The infection proved to be a paratyphoid type B.

In the immunization against typhoid with killed cultures it is now customary to use the killed bacilli of both typhoid and paratyphoid in order to confer immunity to all types of typhoid-like organisms.

The Bacilli of the Dysentery Group.

The first member of this group was discovered by Shiga, a Japanese, in 1897. In its size and shape it is very much like the colon bacillus, but does not ferment sugars like the colon bacillus does. It can be grown from the surface of the large bowel or from the stools of dysenteric patients, and cultures when fed to dogs cause dysentery.

In man the dysentery bacilli will give rise to severe diarrhea, accompanied with cramps, tenesmus, and fever. The stools are streaked with blood and contain mucus. The disease spreads rapidly, sometimes through infected water, sometimes from direct

contact. It lasts from seven to ten days, and frequently is attended with a death rate of from 5 to 20 in 100.

Numerous epidemics have been reported in the United States; among them an epidemic of 350 cases in the village of Tuckahoe, N. Y., which was studied by the writer, together with Dr. Wm. H. Park. The cause of the epidemic was found to be due to an organism almost identical with the one described by Shiga. From a study of the dysentery bacilli found in this and other epidemics in this country, we find that there are a number of bacilli very nearly alike that may cause these epidemics of dysentery.

Individuals that have been infected with dysentery bacilli develop agglutinating substances in the blood that will clump the dysentery bacilli just as in the case of typhoid and paratyphoid infections.

To summarize what has been said of the colon-typhoid-dysentery group: All the members are bacilli of similar appearance, all are to some degree motile, but they differ one from another in their manner of growth, particularly in their ability to ferment sugars. The colon group, although a constant inhabitant of the intestine, gives rise to no infection unless it gains access to tissues outside the bowel. The typhoid and dysentery bacilli are never present in the body under normal conditions, but when they enter the body they cause a characteristic infection. The blood-serum of all infected individuals develops substances that protect against reinfection, and among these substances

are the agglutinins which gather the bacilli together into clumps. The agglutinins caused by infection with the colon bacillus will agglutinate only the colon bacillus; the same is true for the typhoid, paratyphoid, and dysentery bacilli. This peculiarity is made use of in diagnosing the kind of infection present.

The Mucosus Capsulatus Group.

In this group are placed a number of micro-organisms which resemble one another closely in their morphology and manner of growth. The members of this group differ but little from those of the colon group.

The Bacillus Mucosus Capsulatus.

This bacillus was discovered by Friedländer in 1883, and is often called the Friedländer bacillus. It is a short, plump bacillus, with rounded ends, exhibiting considerable variation in size. It may occur singly, in pairs, or in chains. It is not motile and forms no spores. On all the ordinary culture media it grows readily even at room temperature. The most characteristic feature is the transparent capsule about the organism. Exposure to heat of 60° C. destroys the bacillus in a short time.

At the time of its discovery this bacillus was believed to be the chief cause of lobar pneumonia, but it has since been proved that it is responsible for only a small percentage of the cases. In addition to caus-

ing pneumonia, it has been found in suppurations of the nasal sinuses, empyema, pericarditis, and meningitis. No method of immunization has been found as yet.

The Bacillus Lactis Aërogenes.

The *Bacillus lactis aërogenes* is constantly present in milk and, with other micro-organisms, is the cause of souring. It is also present in water, sewage, and feces. It closely resembles the colon bacillus, but differs from it chiefly in being non-motile and having a capsule. It is not a virulent organism, but has been known to be the cause of cystitis.

The Bacilli of the Proteus Group.

The members of this group are putrefactive bacteria capable of breaking down complex proteids into simpler compounds. They are widely distributed, being found in water, soil, air, and wherever putrefaction is in progress.

The chief member of the group is the *Bacillus proteus vulgaris,* a large, thick bacillus that grows readily on the ordinary media. It is motile, but forms no spores. It liquefies gelatin in its growth and produces a characteristic odor of putrefaction. It is not a very virulent organism. It occasionally causes peritonitis, endometritis, pyelonephritis, and enteritis. It has been described as the cause of several epidemics of meat poisoning.

The Bacillus of Rhinoscleroma.

This bacillus is a short, plump rod, in appearance and manner of growth almost identical with the *Bacillus mucosus capsulatus*. Infection with this micro-organism is located usually in the mucous membrane of the nose, mouth, pharynx, and larynx. It produces hard, nodular, inflammatory swellings. Under the microscope large, swollen cells are found in the tissue which contain the bacilli.

CHAPTER VII.

BACTERIA CAUSING ACUTE INFECTIONS.

The Bacillus of Tetanus.

Tetanus, or lockjaw, as it is more commonly called, has existed for many centuries, but the micro-organism causing the infection was not discovered until 1885, when Nicolaier, a German bacteriologist, was successful in producing the disease in animals by injecting them with small amounts of soil.

Morphology The organism is a bacillus of large size, which forms spores readily. It grows on the ordinary culture media, but only when no oxygen is present. The spores are located at one end of the bacillus, and cause a swelling which gives it much the same shape as a drumstick. The spores are very resistant to harmful influences. They will survive dry heat of 80° C. for an hour and 5 per cent. carbolic acid solution for twelve to fifteen hours. Away from sunlight the spores may live for years.

Its natural home is the soil, especially where it has been cultivated and manured. This is due to the fact that tetanus bacilli are present in the intestines of some animals. In the United States the soil in the Hudson Valley and on Long Island seems particularly infectious.

Infection generally occurs by the contamination

Path of infection

of lacerated wounds, especially gunshot wounds with particles of wood, soil, or glass. A great many cases in our country have been due to wounds caused by firecrackers and blank-cartridge pistols, and has led to a crusade against their use on Independence Day. The

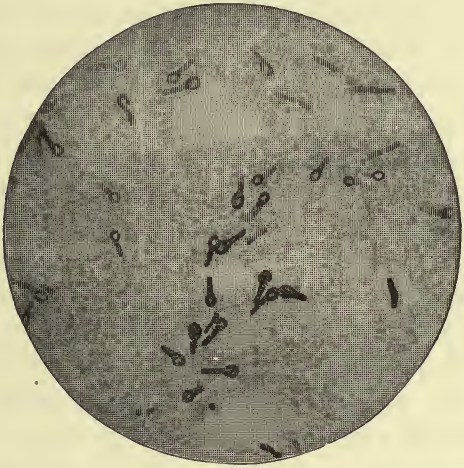

Fig. 8.—Tetanus bacilli. Spore-bearing rods from an agar culture. Mounted preparations, stained with fuchsin. × 1000. (*Fränkel-Pfeiffer.*)

period of incubation is from one to twenty days. The muscular spasm generally begins in the muscles of the face and jaw, making it difficult to chew. This is the origin of the popular name, lockjaw. Gradually other muscles become tight and stiff until finally all the muscles of the trunk and extremities are affected. The least irritation is sufficient to throw all the muscles

into spasm, making the entire body rigid. These spasms are produced by soluble poisons that are formed by the tetanus bacilli at the point of inoculation, and seem to have a special affinity for the tissues of the brain and spinal cord. The poisons are also formed in the culture media, and are among the most powerful known; the poison formed in a bouillon culture being sufficient to cause death when injected into mice in doses of 0.0000005 c.c. Man and the horse are very susceptible to the poison, while chickens are able to resist large doses.

Tetanus toxin

Immunity

It is possible to immunize animals against the tetanus toxin by injecting the poison in very small doses and gradually increasing it. In time the animal can withstand large doses without ill effect. The antitoxin for tetanus is made by injecting the poison in ascending doses into horses until they are thoroughly immunized; then they are bled and the serum, which contains the protective substance, is used to inject into human beings. The use of tetanus antitoxin has not been attended with as much success as the antitoxin of diphtheria. When the symptoms of lockjaw develop it means that the toxin has already attacked the brain and spinal cord; so the antitoxin is of little use. To be effective it must be given at the time of the infection or shortly after.

The Glanders Bacillus (Bacillus Mallei).

Glanders is a malady which occurs principally among horses, but dogs, cats, sheep, and swine are

also susceptible. In rare instances man acquires the disease. It is caused by the *Bacillus mallei,* a small, rod-shaped organism with rounded ends. It can be cultivated easily on the ordinary kinds of culture media, and stains readily, but unevenly, giving the bacillus a granular appearance much like the bacillus of diphtheria. Heat at 60° C. will destroy the bacilli in two hours and 1 per cent. carbolic acid in thirty minutes. Drying destroys them in a short time. In water they may live for two months or more.

The infection in horses occurs generally in the nose or mouth, from the entrance of the bacilli through cracks or wounds in the mucous membrane. After an incubation period of two or three days there is a nasal discharge with swelling of the nasal mucous membrane, which later ulcerates. The cervical lymphatic glands also swell and may suppurate. The disease frequently terminates in pneumonia. Infection through the skin gives rise to a nodular eruption, the nodules later undergoing suppuration. This is called farcy.

The disease may be transmitted to human beings from infected horses or may pass from man to man. The manifestations of the disease in man are much the same as in the horse. It may assume an acute or chronic course, the former nearly always resulting fatally.

The toxins of the *Bacillus mallei* are within the bodies of the organisms, that is, they are endotoxins and are very resistant to heat. Attempts have been

made to immunize animals by the injection of small amounts of the toxin, and have been to some extent successful. It is not possible to immunize man in this way.

Diagnosis

The diagnosis of glanders may be made in several ways. The discharges or the pus may be injected into the peritoneal cavity of guinea-pigs. If the bacillus of glanders is present the testicles become swollen and painful in two to five days. A test may be made for the presence of substances in the blood-serum that will agglutinate the bacilli of glanders. It is done in the same manner as the Widal reaction for typhoid fever. Finally, the toxin of the bacilli made from cultures and called mallein may be injected under the skin of suspected cases. If glanders is present it produces a reaction marked by fever and tenderness about the point of inoculation. The principle upon which this reaction rests is the same as in the tuberculin reaction.

The Bacillus of Influenza.

Influenza, or grippe, is a highly infectious disease that spreads with great rapidity. It is caused by the influenza bacillus. In 1889 an epidemic of grippe started in Russia and in a year's time extended completely around the world. This bacillus is smaller than the bacilli we have studied so far. It is not motile and does not form spores. It grows only in the presence of oxygen. It is difficult to cultivate unless fresh

blood is present on the media. Heat kills the bacillus readily; an exposure for a few minutes at 60° C. is sufficient. Drying also kills it quickly.

The infection manifests itself chiefly in the nose, throat, and bronchi, but may extend to the lungs and give rise to pneumonia. From the nose the infection often extends to involve the accessory sinuses and the middle ear. Exceptionally the infection may extend to the meninges. During the winter of 1912 the writer found the influenza bacilli in the circulating blood of a case of septic endocarditis. The incubation period is from twenty-four to seventy-two hours and the onset is sudden. The bacilli are present in the nose and throat; so to prevent the spread to others these secretions must be collected and destroyed. The bacilli remain in the secretions of the nose, throat, and bronchi for long periods after the acute infection has subsided; in fact, it is probably present all the time in the secretions of some people. Sporadic cases may be explained by this assumption.

The immunity following influenza is of very short duration, and reinfection is very common. Artificial immunity has been attempted by injecting the killed bacilli, but has not proved to be very successful.

The Bacillus of Whooping-cough.

The bacillus causing whooping-cough was described first by two French bacteriologists, Bordet and Gengou, in 1900. It is small in size, much like the

bacillus of influenza, but ovoid in shape. It is found constantly in the sputum of early cases of whooping-cough. It can be cultivated on the usual culture media if blood or its coloring matter is present.

The infection localizes itself in the throat, nose, and bronchial tubes, and is spread by the secretions from these parts. It is transmitted from one child to another, chiefly by direct contact, less often through dwellings and schools that have been infected.

One attack generally protects during life; so cases of reinfection are very rare. The toxins of the bacillus are within the bodies of the bacterial cells (endotoxins). Efforts have been made to immunize against the disease and to modify its course by injecting the killed bacteria. The results have been fairly successful.

The Koch-Weeks Bacillus.

This organism is the cause of acute infectious conjunctivitis, commonly called "pink eye." It resembles closely the bacillus of influenza, but differs from it in growing on media that does not contain hemoglobin.

The Ducrey Bacillus.

This bacillus is of very small size, and has a tendency to form chains. It is not motile and does not form spores. It stains with all the ordinary dyes, but more deeply at the ends. It will grow only on media containing human blood.

Infection with this organism is the cause of chancroid, or soft chancre, an acute, inflammatory, ulcerating sore which occurs generally on the genitals and surrounding skin. It begins as a small pustule which ruptures and becomes an ulcer, having a tendency to spread. The bacilli frequently extend along the lymphatic vessels and involve the adjacent glands of the groin, which may undergo suppuration. The bacilli can be found in the pus and discharges from the ulcers. Infection results generally from sexual contact, rarely from infected dressings, towels, and instruments.

The Micrococcus Melitensis (Malta Fever).

Malta fever occurs among the people living on the shores of the Mediterranean Sea, in some parts of South America, and in the West Indies. It is similar to typhoid fever, but is not so severe, and the mortality rate is not so high. The *Micrococcus melitensis,* the cause of the infection, is readily cultivated on the ordinary laboratory culture media and stains easily. It appears under the microscope in groups and short chains. The infection is spread in the milk of goats, which is the chief source of the milk-supply in Malta, and probably by the mosquito.

Patients sick with Malta fever develop in their blood agglutinins for the micrococcus, which may be utilized in detecting the disease. The use of vaccines made from killed cultures of the micrococcus has been attended with good results.

The Bacillus of Anthrax.

Anthrax is primarily a disease of cattle and sheep, although horses, hogs, and goats are susceptible. The infection may be transmitted directly to man from infected animals or from their hides or wool. The disease exists for the most part in Europe and the East, but in the United States it is rarely met with.

The anthrax bacillus was the first micro-organism definitely proved to be the cause of a specific disease. It is a large, straight rod with square-cut ends. It is not motile. In cultures they are prone to form long chains or threads. Spores are formed, which are situated in the center of the bacterial cells. They are very resistant to harmful influences. While the bacillus itself may be destroyed by an exposure of ten minutes to heat at 54° C., the spores require an exposure of three hours' dry heat at 140° C. and live steam for five to ten minutes. They will resist drying for years. A 5 per cent. solution of carbolic acid requires forty days to kill them, and bichloride of mercury 1 : 1000 forty minutes. Direct sunlight destroys them in six to twelve hours.

Portal of entry

The bacillus finds its way into the bodies of cattle principally through the alimentary tract. In man the portal of entrance is more often through the skin and respiratory tract. Those handling live stock, butchers, and tanners are most liable to contract the disease. The first symptom of anthrax is a pustule or boil,

which progresses to ulceration and gangrene. If this is opened promptly recovery may follow. Among those working on raw wool, hides, and horsehair the disease may be acquired by inhaling the spores. Infection contracted in this manner causes a pneumonia, often called wool-sorters' disease.

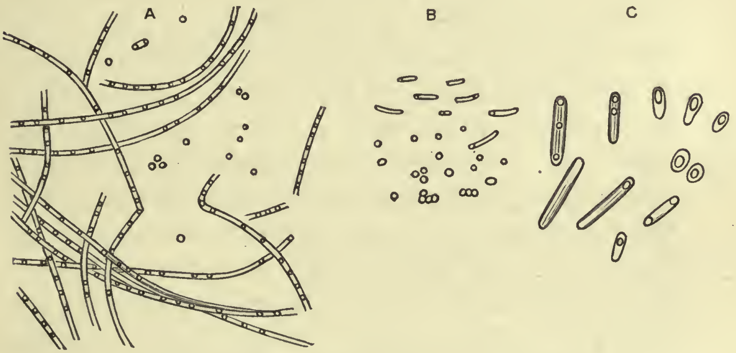

Fig. 9.—Anthrax bacilli. Spore formation and spore germination. *A,* from the spleen of a mouse after twenty-four hours' cultivation in aqueous humor. Spores arranged in rods like a string of pearls. × 650. *B,* germination of spores. × 650. *C,* the same, greatly magnified. × 1650. (*Koch.*)

The disease is prevented from spreading by destroying the infected animals, burying their bodies and disinfecting the stables.

No toxins are formed by the anthrax bacillus. It is possible to immunize animals by injecting the bacilli that have been attenuated by long growth at a temperature of 42° C. The blood-serum of animals immunized in this way contains the protective sub- **Immunity**

stances, and may be used to develop a passive immunity in other animals.

The Bacillus of Plague (Bacillus Pestis).

The bacillus of bubonic plague was discovered by Kitasato and Yersin during the epidemic in China in 1893. It is a short, thick bacillus with rounded ends. In old cultures atypical forms are found, some like cocci, others club-shaped like the diphtheria bacillus. It stains more deeply at the ends than in the center. It is not motile and does not form spores. It will grow only in the presence of oxygen. In dark, moist places the organism will live for months or years. In the sputum and pus from patients it lives for one or two weeks. In cadavers they may live for several weeks. Dry heat destroys the bacillus in one hour, boiling in a few minutes. Direct sunlight requires four or five hours. Carbolic acid (5 per cent.) and bichloride of mercury (1 : 1000) destroy them in ten minutes.

The plague raged from the sixth to the seventeenth century, and in the fourteenth century the black death, as it was called, destroyed one-quarter of the population of Europe. The great plague in London in 1665 destroyed 70,000 people. The disease subsided then and remained practically dormant until 1894, when it broke out in Hong Kong. It spread thence to other countries, and a small epidemic occurred in San Francisco in 1907.

The infection may enter through the skin or by

way of the respiratory tract, and the symptoms of the disease manifest themselves after an incubation period of three to seven days. The symptoms following infection through the skin are characterized by headache, high fever, stiffness in the limbs, restlessness, and anxiety. Collapse frequently follows. The lymphatic glands are enlarged, particularly those in the inguinal region, which are called buboes. Infection by way of the respiratory tract begins abruptly with pneumonia. The mortality rate for this disease is very high,—80 to 90 per cent.

The way the disease is spread

The bacilli of the plague are present in the swollen lymphatic glands, the sputum, urine, and intestinal discharges, and the infection may be spread directly from these sources. The chief way, however, in which the infection is spread is from the bites of the rat-flea, which transmits the disease from rat to rat and from rat to man. Unsanitary conditions have little to do with the occurrence of the plague, except that they favor infestation with rats. To prevent the disease from spreading, all patients must be quarantined, all discharges destroyed, and all articles that have come in contact with the patient disinfected. To prevent rats from breeding, all stables and outhouses should be cleaned up, and all possible sources of food-supply cut off. Dwelling-houses should be made rat-proof as far as possible. The importation of the disease into ports not infected should be guarded against by fumigating ships from infected countries and the isolation of suspected cases during the period of incubation.

Ways of prevention

The toxins of the *Bacillus pestis* are both endo- and extra- cellular. It is possible to immunize animals and, in their blood, substances that will agglutinate the bacilli are found. They may be used in the diagnosis of the disease. In human beings an immunity develops after one attack. A protective serum has been used against the disease, and is said to reduce the mortality rate 20 to 25 per cent.

The Bacillus Pyocyaneus.

The discharges from open wounds occasionally have a green color, the cause of the color in these cases being due to a pigment formed by the *Bacillus pyocyaneus.* It is a short, actively motile rod, having a tendency to form chains in fluid media. It can be readily cultivated in the presence of oxygen, and is easily identified because it stains the media upon which it grows a brilliant green. It forms no spores.

This organism possesses no great virulence, and may live without producing injury on the skin, and in the respiratory and intestinal tracts of animals and man. It may, however, be the cause of serious infections, but in such cases it is due to greatly lowered resistance in the patient rather than to the virulence of the bacillus. It may be the cause of otitis media and diarrhea and gastroenteritis in children. Cases of general sepsis, liver abscess, and pericarditis have been attributed to it.

The pigment produced is of two kinds; one is

called pyocyanin, soluble in chloroform; the other is a fluorescent pigment soluble in water. In old cultures a ferment-like substance is formed called pyocyanase, which has the property of dissolving some of the other forms of bacteria. It has been used to destroy diphtheria bacilli that persist in the throat after recovery. The toxins formed by the bacillus are both endo- and extra- cellular. Immunity in animals is produced with much difficulty, but in man no way of producing immunity has been devised.

The Spirillum of Asiatic Cholera.

The micro-organism causing cholera is a small, curved rod, often shaped like a comma, and therefore called the comma bacillus. When two are placed end to end they are S-shaped. True corkscrew forms occur, particularly in cultures in fluid media. The spirillum was discovered by Professor Koch in 1884. It is motile, being propelled by a single flagellum placed at one end, and grows on all the laboratory media in the presence of oxygen. No spores are formed.

Distribution of the disease

Cholera exists constantly in India and countries of the Orient. It has been carried occasionally to other countries, causing epidemics. A very bad epidemic occurred in Hamburg in 1892. In this country the disease has been imported on several occasions, but no epidemic has developed since 1873. Strict measures are taken at the chief ports,—New York,

New Orleans, and San Francisco,—to quarantine all suspects among the immigrants.

Path of infection Infection always takes place by way of the alimentary tract, from infected water and food. While infected water is the most common cause, the infection may be carried on vegetables that have been washed in infected water, particularly those used as salads. Flies can deposit the infection on bread, butter, meat, and other foodstuffs. Direct infection from handling soiled bed-linen is not uncommon, as is shown by the greater frequency of the disease among washerwomen during epidemics. The onset of cholera, following an incubation period of two to five days, is sudden, with frequent watery stools, high fever, and great prostration. In the severe cases death may occur in eight to twelve hours. The infection localizes itself in the intestine. The spirilla are never found in the circulating blood, consequently the stools alone are infectious and may continue to be for months after recovery. People who carry the spirilla of cholera in the intestine after recovery are called cholera carriers.

Prevention To prevent the disease during epidemics all drinking-water and milk must be boiled, and no meat or vegetables eaten unless cooked. Great care must be taken to exclude flies from contact with foods. Bed-linen, clothing, and utensils used by patients should be soaked in 5 per cent. carbolic solution, and subsequently boiled in the laundry. Attendants upon cholera patients should be careful to disinfect the hands after handling the patients. The stools are best dis-

infected with 5 per cent. carbolic solution, and the disinfection should be continued for some time after recovery.

The constitutional symptoms that accompany cholera are due to the toxins formed by the spirilla in the intestines. They are partly thrown out by the organisms, that is, soluble toxins, and partly retained in the body of the bacterial cells and set free only after their death. It is possible to immunize animals against cholera by injecting small amounts of the killed cultures or very small doses of the living organisms. The blood-serum of animals immunized in this way contains substances that dissolve the spirilla—bacteriolysins, and substances that clump them—agglutinins. The agglutinins are made use of in diagnosing cholera in the same way as in the diagnosis of typhoid fever (see Widal reaction). Human beings that have recovered from cholera are immune to the disease, but they remain so for only a few months. Efforts to protect human beings by injecting the killed cultures have been made in India on a large scale, but the results have been only partially successful.

Immunity

The Bacillus of Diphtheria.

Diphtheria is an infectious disease caused by the diphtheria bacillus, sometimes called the Klebs-Löffler bacillus, after the two men who discovered it. The word diphtheria is derived from a Greek word meaning leather, because of the characteristic false mem-

brane that forms in the throat. The bacillus causes infection most frequently in the throat or nose, although it may grow on the gums or about the teeth. It is possible for diphtheria bacilli to cause infection of the middle ear, the sinuses of the nose, and the lung (pneumonia). Rarely it extends to the skin about the mouth, or to the genitalia or rectum.

Morphology

The diphtheria bacillus is one of the few types that can be identified by its appearance under the microscope, because its shape is different from other bacteria. Three fairly distinct forms are recognized:

A. The granular type, the granules generally at the ends.

B. The barred type, the granules so arranged that the cell looks cross-striped like a barber's pole.

C. The solid type, with ends often club-shaped.

They will grow on most of the laboratory media, but thrive best on media that contains blood-serum.

It stains readily with dyes, is not motile, and forms no spores. Outside the body direct sunlight kills the bacilli in half an hour, but in the dust they will live for months. On slate-pencils, cups, glasses, or toys such as children put in their mouths, they will live for weeks.

In the nose and throat the bacilli produce, by their multiplication and by the poison thrown out by them, death of the mucous membrane, which appears white and like a membrane. The membrane may extend into the nose or larynx, causing an obstruction

to breathing. By far the greater damage is caused by the poisons that are absorbed and affect the various organs and tissues, particularly the muscle of the heart, the kidneys, and the nervous system. The

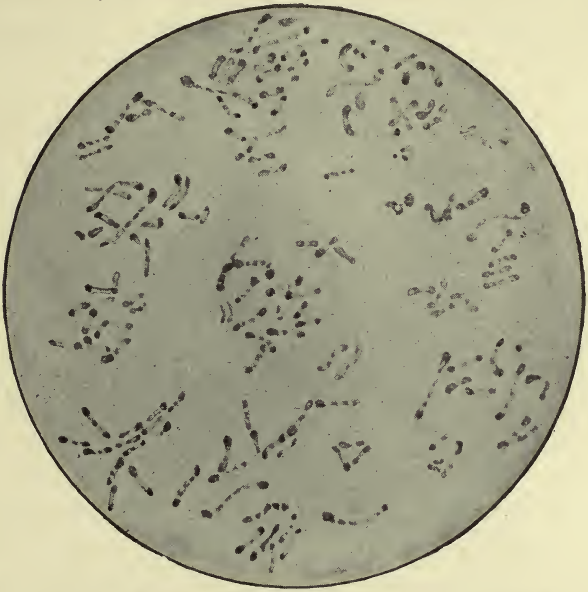

Fig. 10.—Bacillus diphtheriæ. × 1000. (Drawing by *E. L. Oatman, M.D.*)

effect of the poisons upon the heart results sometimes in sudden death, following even slight exertion like sitting up in bed. Paralysis may follow diphtheria when the nervous system has been attacked.

Diphtheria in the throat and nose is detected by finding the bacilli in the wipings made from the mem-

Diagnosis

brane. It is not safe to rely solely upon the presence and appearance of a membrane, because membranes may be due to infection with micro-organisms other than the diphtheria bacilli, such as the staphylococcus and streptococcus. In order to say whether a membrane is due to diphtheria or not, a sterile cotton swab is rubbed over the membrane, and then rubbed on the surface of a tube containing coagulated blood-serum. The tube and swab are now sent to the laboratory and incubated at body temperature for twelve or twenty-four hours in order to allow the bacteria present to multiply. The growth is now smeared on glass slides, stained, and examined under the microscope. If diphtheria bacilli are present they can be readily identified by their appearance.

Spread of the disease

The disease is spread to others chiefly by means of the bacilli thrown from the nose or mouth by coughing and sneezing. The sputum contains the bacilli in large number. Indirectly the disease is spread from the sputum by means of drinking-cups, handkerchiefs, door-knobs, and among children from pencils, chewing gum, toys, and other things that are handled and passed about. Cats, rats, and mice may carry the infection, and flies may deposit it on food and milk. Infected milk has been the cause of a number of epidemics.

Duration of quarantine

The most important and first precaution to be taken in limiting the spread of diphtheria is quarantine. This means the complete isolation of the sick person. The length of the quarantine cannot be determined by

the condition of the patient or by the appearance of the throat, because it is possible and frequently is so that although the patient is apparently well and the throat clear, the bacilli of diphtheria are still there. In order to tell when the bacilli have disappeared a wiping of the throat is made just as described in

Fig. 11.—Organisms of Vincent's angina, showing spirillum and fusiform bacillus.

making the diagnosis, incubated and examined. Two such cultures free from diphtheria bacilli are considered sufficient evidence that the patient is no longer able to transmit the disease to others. Among healthy persons, particularly attendants upon diphtheria patients, the bacilli may be carried in the throat for long periods of time without causing any of the symptoms of the disease. Such persons are called carriers, and can transmit the disease to others.

Disinfection

All discharges from the nose and mouth should be collected on paper napkins and burned. A paper napkin should be held over the nose and mouth while coughing or sneezing. All bed-linen and utensils used by the patient should be soaked in a 5 per cent. solution of carbolic acid and boiled. The sickroom must be fumigated and cleaned after the manner already described under Disinfection. All well persons, including the nurse, should receive an immunizing dose of antitoxin. Nurses should wear a gown to protect the uniform and a cap over the hair.

The curative property of antitoxin was discovered by von Behring in 1894, and is now in universal use for the cure and prevention of diphtheria. By the use of antitoxin the fatal cases have been reduced to one-quarter of those formerly resulting in death. In New York from 1895 to 1910, 80,000 people received immunizing doses of antitoxin, and out of this number only 177, or 0.2 per cent., contracted diphtheria, and but one of these resulted fatally. The immunizing dose protects from two to six weeks. Occasionally the injection of antitoxin is followed after a few days by a feeling of malaise, skin eruption, vomiting, albuminuria, and swelling of the lymphatic glands. This condition is due to anaphylaxis, or an increased susceptibility on the part of the patient to certain constituents of the antitoxin, probably the horse-serum, which contains the protective substance. A few cases of sudden death following the injection of diphtheria antitoxin have been attributed to anaphylaxis.

Serum sickness

CHAPTER VIII.

BACTERIA CAUSING CHRONIC INFECTIONS.

The Bacillus of Tuberculosis.

Tuberculosis is an infectious disease caused by the tubercle bacillus, which was discovered by Professor Koch in 1882. The organism is widely distributed over the world, and is pathogenic for the lower animals as well as for man. It is frequently found in cattle, less often in goats and swine, rarely in sheep, horses, dogs, and cats.

The bacillus is a slender rod, slightly curved, with rounded ends. It is purely parasitic, that is, it will not grow or multiply outside a host. It is never found save in the bodies and discharges of animals affected by the disease, or in the dust or upon articles which the discharges have contaminated. It is not motile, does not form spores, and is cultivated on artificial culture media with difficulty. It cannot grow without a liberal supply of oxygen, and only at body temperature. It is killed by moist heat at 70° C. in ten minutes, but dry heat at 100° C. requires one hour. Direct sunlight destroys them in two hours, but when protected from sunlight they can live for a year. Morphology

There are four kinds of tubercle bacilli: the human; the bovine, chiefly found in cattle; the avian, found in birds, and the reptilian. The human tubercle

bacillus is only slightly infectious for cattle, but the bovine bacillus is infectious for human beings, particularly young children, who may become infected from the milk of tuberculous cattle.

Staining The tubercle bacillus does not stain readily, but once stained it is difficult to decolorize it with acids. For this reason it is said to be acid-fast. The method employed in staining is as follows: The suspected material is spread thinly on a glass slide and dried. The preparation is then covered with fuchsin, a red dye to which has been added a small amount of carbolic acid solution and steamed, the heat quickening the staining. Then the preparation is washed off in water and decolorized with a 5 per cent. solution of nitric acid. This is allowed to act until all the red color is removed. After washing again in water the preparation is again stained with a methylene-blue solution. The picture produced by this method shows the tubercle bacilli unaffected by the acid decolorizer and stained red, while all other organisms are stained blue. In this way the tubercle bacillus may be detected in discharges from suspected cases.

Tubercle bacilli in urine In collecting urine for examination for tubercle bacilli it is important to know that the smegma bacillus, a non-pathogenic organism found in the secretions about the genitalia, possess the same staining peculiarities as the tubercle bacillus; so that great care must be used to exclude it from the urine by careful cleansing of the external genitalia and collection of the urine by catheter. In fluids like urine, pleural effu-

sions and ascitic fluid the number of tubercle bacilli is always small; so to detect them the inoculation of guinea-pigs with the fluid is often practised. If tubercle bacilli are present in the fluid injected, the disease develops in the animal after a period of three to six weeks.

Exudates

The tubercle bacillus may cause infection by entering the body in the following ways:—

Path of infection

Hereditary transmission, long believed to be a common occurrence, has not been proven among human beings. In very rare instances the bacilli may pass from the mother to the child in the uterus, but this depends upon some injury or disease of the placenta.

Respiratory: This is the most common way that infection takes place. The sputum of consumptives is the direct carrier of the infection. Deposited in houses, on floors and streets, the bacilli become incorporated with the dust which is breathed in by those in close contact with the patients. The careless disposal of sputum is responsible for the greatest number of infections.

Intestinal: This is more common in children than in adults. The bacilli gain entrance through the milk from tuberculous cattle or food infected by consumptive people. The habit children have of putting everything into their mouths is responsible for many infections, particularly in houses where consumptives are living. The bacilli resist the action of the acid in the stomach, and in the intestine may penetrate the

wall and lodge in the mesenteric glands. From this point they may be carried to remote tissues or organs.

Cutaneous: The bacilli may enter the skin through injuries or abrasions, giving rise to the disease known as lupus vulgaris.

Tubercles Once in the body, the tubercle bacilli may become localized in any tissue or organ, and there proceed to multiply. The result is the formation of a nodule or tubercle, from which the disease takes its name. The tubercles are about the size of a millet-seed, and at first are distributed separately in an organ. As they grow larger the central portion is poorly supplied with blood, so that it degenerates, softens, becomes cheesy, and finally may ulcerate. Tubercles that are placed close together may coalesce and go on to ulceration, causing large abscesses. If the tubercle bacilli reach the circulating blood they may be carried to many organs and tissues, at once causing a tuberculous septicemia or miliary tuberculosis. In such cases at autopsy the miliary tubercles are found everywhere in the body.

It is well to distinguish between the words "tubercular" and "tuberculous," as they are often used incorrectly. The word tubercular means nodular and has no reference to the nature or cause of the nodule. Tuberculous, on the other hand, is an adjective used to indicate tissues infected with tubercle bacilli.

Toxins The damage done in tuberculosis is due almost entirely to the absorption of the toxins formed by the tubercle bacillus. These are of two kinds: an extra-

cellular or soluble toxin, to which is attributed the fever, headache, loss of appetite, and so on, and an endotoxin which causes the irritation of the tissues leading to the formation of the tubercle. The absorption of these toxins causes the formation of antibodies, but not in sufficient amount to cause immunity. The toxins of the tubercle bacilli may be obtained from cultures, and are used under the name of tuberculin in the diagnosis and treatment of the disease. The tuberculin reaction used in the diagnosis is based upon an observation made by Professor Koch, that animals having tuberculosis were very sensitive to the poison, and when injected with even a small amount of tuberculin developed fever, headache, nausea, vomiting, and general malaise, while the diseased tissues became temporarily more inflamed. Healthy animals were unaffected. This method has been employed among tuberculous patients, using from 1 to 10 milligrams of the tuberculin. Simpler methods have more recently been used, such as the von Pirquet test, in which the tuberculin is introduced into the superficial layers of the skin with a scarifier, and the Moro test, in which the tuberculin is rubbed in, in the form of an ointment. In the first method a positive reaction is manifested by fever, headache, and so on, as described above, but in the cutaneous tests there is only a local redness about the point of inoculation. A positive test means that tuberculosis is present in the body, but it does not tell us where or whether it is active or not. In children, a positive reaction usually means active disease.

Tuberculin reaction

Tuberculin treatment

Tuberculin administered in increasing doses, too small to cause a reaction and at fixed intervals, develops a tolerance for the poison, and so an immunity. This method of treatment is being widely used, and while the results are not prompt, the consensus of opinion is that it exerts a beneficial effect on the course of the disease.

Public Health measures adopted in the crusade against tuberculosis

During the last ten years great efforts have been made to check the ravages of this disease; in fact, a crusade has been carried on that has become worldwide. Among the measures that have been advocated are the registration of all cases of tuberculosis by departments of health, the establishment of institutions sufficient to care for the advanced cases, dispensaries where suspected cases may be examined and subsequently visited by nurses who instruct the sick in the proper way to disinfect the sputum, stools, and urine, and the disinfection of all houses occupied by tuberculous patients before being reoccupied. More general measures, such as better sanitary conditions in factories, schools, and dwellings, have been brought to the attention of the public, and have created a public sentiment that is now bearing fruit. As a result of this crusade, it is not too much to expect that the death rate from tuberculosis will be materially reduced, and that the spread of the disease will be checked.

The Bacillus of Leprosy.

The bacillus causing leprosy was found by Hansen, a Norwegian, in 1871, in the nodules of leprous

patients. It is a short rod about the size of the tubercle bacillus, which it resembles closely both in appearance and in staining peculiarities. It takes stains with difficulty, but once stained it resists decolorizing with acids. For this reason it is spoken of as being acid-fast. It is very difficult to cultivate on the culture media at our disposal. Efforts to transmit the disease to animals have not been successful.

Distribution of the disease

Leprosy is one of the oldest diseases known, and Dr. Osler says it existed in Egypt three or four thousand years before Christ. It is referred to many times in the Bible, but there is reason to believe that other diseases were included under the same name. The disease has continued to exist to the present time, but was particularly prevalent in the Middle Ages. At present it exists in Iceland, Norway, Sweden, Russia, Spain, Portugal, England, West Indies, China, India, and the Philippines. In the United States small numbers of cases are to be found in Louisiana, Minnesota, Florida, and Texas, with isolated cases widely scattered.

The disease manifests itself either as tubercular leprosy or as anesthetic leprosy. In the former, nodules develop in the skin which soften and finally form discharging sores. In the anesthetic form the nerves are principally affected, and this leads to loss of sensation in the skin. Both forms may exist at the same time.

The way that infection takes place is not positively known, but many believe that it enters the skin

or mucous membranes through close personal contact. While hereditary transmission cannot be denied, no instance has so far been recorded. The infectious material is found in the discharges from the open sores, in the urine, milk, blood, sputum, and nasal secretions. The last are especially infectious.

The spread of the disease is checked by the segregation of the lepers in the communities where the disease prevails. Attendants upon leprous patients should know that the disease is one of the most difficult to contract of all the infectious diseases, and that it is very rare for nurses to be infected while attending cases. Careful attention should be given to disinfecting the nasal discharges and sputum.

CHAPTER IX.

THE DISEASES CAUSED BY THE MOLDS, YEASTS, AND HIGHER BACTERIA.

REFERRING back to the classification of the fungi given in chapter ii, there still remains to be considered the hyphomycetes, or molds, and the blastomycetes, or yeasts. Under the head of higher bacteria are organisms having characters that make it difficult to classify them either as molds or yeasts. The most important of the diseases caused by the higher bacteria is:—

ACTINOMYCOSIS.

This is an infection generally running a chronic course, caused by the actinomyces, or ray fungus. It prevails chiefly among cattle; but sheep, dogs, cats, horses, and swine are also susceptible. It occasionally occurs in man.

The parasites can be seen by the naked eye, in pus from the abscesses, as minute, yellow masses, often called sulphur granules. If the granules are examined under the microscope they are found to be made up of a central thick mass of filaments which radiate at the periphery. It is because of this radial arrangement that the parasite is called the ray fungus. The ends of the filaments are often club-shaped.

The infection is located most often about the

mouth or in the throat. It starts as a nodule, hard at first, but later undergoes softening and finally suppurates, causing a discharging sinus. Infections of the skin, lungs, intestines, and appendix have been described. The parasite is supposed to enter the body

Fig. 12.—Actinomyces hominis (lung). × 350. (*Lenhartz-Brooks.*)

in grain, oats, barley, or rye, and in cattle from hay or straw.

The disease is not highly infectious, and all danger is removed by careful disinfection of the discharges containing the pus.

Yeasts.

Yeast-cells are much larger than bacteria; they are oval in shape and have a thick cell-membrane.

The protoplasm contains vacuoles and one or more nuclei. The manner of reproduction is characteristic; the capsule protrudes and forms a bud and contains a part of the protoplasm and a half of the nucleus. It gradually grows larger, and is eventually pinched off to become another cell. The cells frequently contain spores, which are liberated when the cell disintegrates.

The most important property of yeasts is the fermentation of sugars whereby the sugar is changed into ethyl alcohol and carbon dioxide. Commercially the yeasts are used in a variety of ways, but chiefly in the manufacture of beers and wines. Few of the yeasts are infectious for man, and but one will be mentioned.

Blastomycosis.

This infectious disease is caused by a yeast called the blastomyces. In appearance it corresponds to the yeast-cells described above, having a thick cell-wall, with one or more nuclei in the protoplasm, and vacuoles. Occasionally it forms threads called mycelia (sing. mycelium).

The skin is most often affected. Small nodules form, which soften and discharge a yellow pus. They spread slowly and sometimes involve a considerable area of skin. Infection of the lungs is more serious and often leads to pneumonia. A few cases of general infection have been reported with abscesses in the liver, spleen, and lungs.

Where the organisms that cause the disease come

from is not known, but in skin infections it is presumed that they enter along the hairs or through small abrasions. It is not a very infectious disease, and the infection of others may be prevented by disinfecting the pus discharged.

Fig. 13.—Microsporon furfur. (After *Lenhartz.*)

Molds.

The molds in their structure are much more complex than the yeasts. They are characterized by the formation of mycelial threads and terminal organs of reproduction called hyphæ. They may be seen growing on decomposing substances, and look like little pieces of cotton. Of the many kinds of molds, but a few are pathogenic for man.

THRUSH.

This occurs in infants and young children, causing sore mouth. It is caused by a mold called the *Oidium albicans.* The mucous membrane is red and dotted with small, white flakes, which contain the organism.

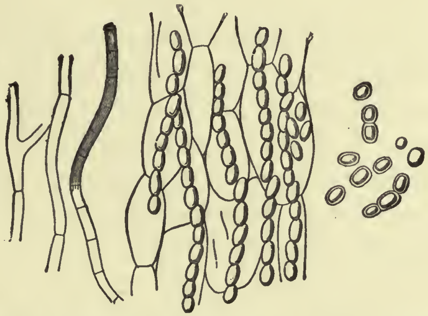

Fig. 14.—Trichophyton tonsurans. (After *Bizzozero.*)

PITYRIASIS VERSICOLOR.

The infectious mold here is the *Microsporon furfur,* which lives on rather than in the skin. It produces yellowish, scaly patches on the chest, back, or abdomen, which may spread over large areas of the skin. When scratched, the growth can be removed in fine scales which contain the mold. It affects chiefly the uncleanly.

FAVUS.

The mold causing favus is called the *Achorion Schönleini,* after its discoverer. It attacks the hair-fol-

licles, especially of the scalp, and forms yellow crusts about the base of the hairs. If the crusts are removed and examined under the microscope, the parasites can be found in them. The disease is very resistant to treatment.

Ringworm.

This is a very common affection among children, and is caused by the *Tinea trichophyton.* There are three types of the parasite: the *Tinea tonsurans,* which attacks the hairs of the scalp; the *Tinea sycosis,* which attacks the hairs of the bearded part of the face, and the *Tinea circinata,* which attacks the skin. It starts as a slightly elevated, scaly spot, which gradually widens, forming a red, scaly patch, with raised edges. The hairs invaded by the parasites break off and leave the center devoid of hair. The disease spreads from one person to another by direct contact.

CHAPTER X.

THE BACTERIA IN WATER AND MILK.

The Bacteria in Milk.

From its appearance and taste little can be known of the bacterial content of milk. It may be teeming with bacteria, yet give no indication of their presence. In fact, ordinary market milk contains from 100,000 to 1,000,000 bacteria in every cubic centimeter.

How do these bacteria get into the milk? In the udder of the healthy cow the milk is practically free from bacteria, but they live in the milk-ducts in the teats, and get into the milk as it is drawn. The chief source of bacteria in milk lies in the uncleanly methods of collecting it. Many get in from the dust-laden air of the cow-stable, from the dirt on the hide of the cow, unclean milk-pails, and from the dirty hands of the milkers. It is a true saying that the number of bacteria in milk is an index of the cleanliness with which it has been collected. Once in the milk, the bacteria multiply with great rapidity, for milk is an excellent medium for the cultivation of bacteria. The temperature of the milk for some time after it is drawn also favors their development.

Prevention of contamination

To prevent the contamination of milk with excessive numbers of bacteria, all that is required is cleanliness,—clean stables, clean cattle, milkers with

clean hands, and clean milk-pails. Immediately after the milk is drawn, it should be cooled to 5° C. (40° F.) and kept at this temperature until sold.

Pasteurization

On account of the difficulty in maintaining strict supervision over the milk-supply in cities where the milk is collected from a wide area, we have come to the conclusion that pasteurization is essential to render the supply safe for use, particularly in infant feeding. Pasteurization is accomplished by heating the milk to 60° C. (140° F.) for twenty minutes or 65° C. (158° F.) for fifteen minutes. The milk is immediately cooled to 5° C. (40° F.) and kept at this temperature till used. Milk to be used in feeding infants should be modified and poured into the nursing bottles before being pasteurized. It should be used within twenty-four hours. The pasteurization kills all the bacteria, but not the spores. If the milk is cooled as directed, the spores will not develop.

The bacteria usually present in milk are harmless in so far as they are able to produce specific disease; but while they may be considered as harmless for healthy adults, they may be very dangerous for infants and sick persons. The great loss of life among infants under 2 years of age from intestinal or diarrheal diseases show this. During the summer months, when the number of bacteria is more than at any other time of the year, the milk undergoes chemical changes which lead to disturbances in digestion and infection of the intestines.

Diseases other than these caused by the ordinary

Diseases transmitted by milk

dirt bacteria may be spread in milk. Many epidemics of scarlet fever, typhoid fever, measles, and diphtheria have been traced to infected milk. The infection is introduced into the milk at the dairy, usually by someone sick with the disease in question.

The transmission of tuberculosis in the milk from tuberculous cattle is believed to be of common occurrence, particularly among infants. The tubercle bacilli may pass through the walls of the intestine without causing any disease of the intestinal wall itself, and lodge in the mesenteric lymphatic glands. They may lie dormant for years and later on, when the resistance is lowered by disease or by unsanitary conditions of living, become active and cause tuberculosis in whatever organ or tissue they may have lodged. The milk from cattle having tuberculosis of the udder is the most dangerous; but even when the udder is healthy and the disease located in other organs, the milk may contain tubercle bacilli. Not only is the milk from tuberculous cattle infectious, but also the products—butter and cheese—made from the milk. From what has been said, it is easy to see the danger of using raw cows' milk for infant feeding without positive assurance that the cows have been tuberculin tested and are free from tuberculosis.

The Bacteria in Water.

Water as it falls in the form of rain is free from bacteria. It begins to be contaminated with bacteria when it reaches the dust-laden air above the earth, and

after it reaches the ground the number of bacteria is greatly increased from the soil. As it drains from the surface of the earth or percolates through it, it is classed either as surface water, of which ponds, lakes, or rivers are examples, or as ground water, which feeds wells. Surface water always contains large numbers of bacteria, but the water in wells contains only a few on account of the filtering action of the soil. While the number of bacteria in surface water is large, there is going on constantly processes of purification which keep the number in check.

Natural methods of purification

First, there is sedimentation or the sinking of impurities by reason of their weight. The effect of sedimentation can be seen after floods, where the mud and dirt is found over the flooded areas. Sedimentation takes place slowly; so in streams that are flowing fast it cannot be relied upon to remove much of the impurities. Aëration is another factor. This means the mixing of water with air, as takes place, for example, in water-falls. It does not destroy the bacteria but it removes objectionable odors. Sunlight exerts a powerful destructive action on the bacteria in water, provided the depth of the water is not too great for the sunlight to penetrate. Unfortunately, the penetrating power of sunlight is not great; so its action is limited to the upper layers of the water. The ground water is purified by the filtering action of the soil, which is very efficient, provided the amount of water to be filtered is not too great and it is not required to work continuously.

The ordinary soil bacteria in water are harmless. It is only the pathogenic bacteria in the soil from human excreta, like the typhoid and dysentery bacilli and the cholera spirilla, that get into the water and cause disease. In testing the water to see whether it can transmit these diseases or not, it is almost useless to look for the disease-producing bacteria themselves, because they are extremely difficult to find. The presence of intestinal bacteria is looked for, particularly the colon bacillus, and when they are found in large numbers the water is condemned for drinking purposes: first, because drinking-water should not contain substances excreted from the intestines of man or animals, and, secondly, water that does contain such substances is constantly open to infection with bacteria that produce disease.

Artificial meth ds of purification

Nowadays practically all surface waters are contaminated with human sewage. To render these waters safe for drinking purposes in cities, the natural process of water purification cannot be relied upon, and artificial methods, based on filtration, are employed. The water may be made to percolate through beds made of fine gravel and covered with a thick layer of fine sand. The dirt and slime in the water cling to the small particles of the sand, and only the water free from its impurities is permitted to pass through. About 90 per cent. of the bacteria in water can be removed by sand filtration. In mechanical filtration, a chemical substance like alum is added to the water in sufficient quantity to coagulate the solid and ex-

traneous materials, which sink and carry the bacteria with them. In the home, water may be rendered pure by filtration through porcelain filters, and, where these are not available, by boiling. The flat taste of boiled water may be removed by passing the water from one container to another so that air may be mixed with it.

CHAPTER XI.

DISEASES CAUSED BY PROTOZOA.

In the classification of micro-organisms in chapter ii, they were divided into two great classes,—those belonging to the animal and those belonging to the vegetable kingdom. So far we have studied only the vegetable micro-organisms,—the molds, yeasts, and bacteria. The protozoa (sing. protozoön) represent the lowest form of animal life, and are composed of a single cell made up of a nucleus surrounded by a mass of protoplasm. The protoplasm is concerned with the nutrition of the cell, while the nucleus controls the vital functions, particularly reproduction. Comparatively few of the many species of protozoa are known to be pathogenic for man. The life cycle of the protozoa is peculiar in that part is lived inside the body of some animal, and part outside the body. During the cycle they may take on various shapes and sizes.

Amebic Dysentery.

This is a chronic form of dysentery, frequently associated with abscess of the liver, which is especially prevalent in the tropics; in fact, the disease is sometimes called tropical dysentery. It is found quite frequently in the Southern States and occasionally in the Northern States. It is caused by the *Ameba histo-*

lytica, a protozoan parasite, larger than any of the bacteria that have been studied. It is composed of an outer clear zone, a granular inner zone which contains the nucleus, and a cavity called a vacuole. It moves by extending a portion of the outer clear zone, called a pseudopod, into which the rest of the cell body flows. The pseudopods may also embrace small particles of food and make them part of their bodies. The amebæ are very sensitive to changes in temperature, and motility can be seen only at body temperature. Reproduction takes place either by simple division or by the formation of smaller cells called daughter-cells, which are set free and develop into parasites.

The infection with amebæ comes from drinking infected water and possibly from eating uncooked vegetables that have been washed in infected water. After being ingested the amebæ lodge in the intestine and cause inflammatory changes that lead to ulceration. It is not uncommon for the amebæ to be carried from the intestine to the liver, where they may cause abscesses. The stools contain the amebæ and, to prevent the disease from spreading, the stools must be disinfected with 5 per cent. solution of carbolic acid. In countries where the disease prevails, all water used for drinking purposes should be boiled, and no uncooked vegetables eaten unless washed in boiled water.

The diagnosis of amebic dysentery is made by finding the amebæ in the stools. This can be done by examining under the microscope the mucus or pus in the stool or that obtained by passing a rectal tube high

into the bowel. The material to be examined must be kept warm in order to preserve the motility of the amebæ.

The disease is of long duration and no specific method of treatment is known. The drug emetin has been used much of late, with success.

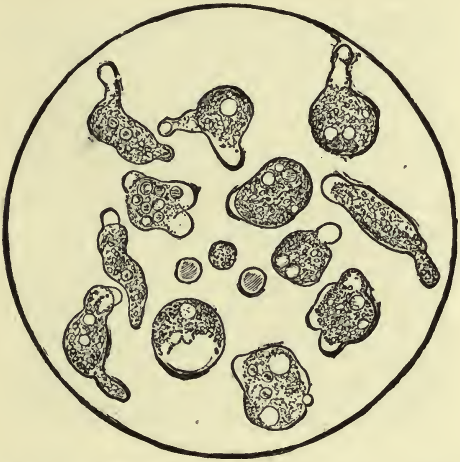

Fig. 15.—Ameba coli. From dysenteric stool. (Zeiss Apochr., 1; oil immersion, 1/12.) (After *Lösch.*)

Syphilis.

The *Treponema pallidum* is the infectious agent causing syphilis. It was discovered in 1905. It is a very delicate spiral with from 3 to 12 turns and with pointed ends. The cultivation of the organism was not successful until 1911, when Dr. Noguchi, at the Rockefeller Institute in New York, found that they

Morphology

would grow only when all oxygen was excluded and fresh tissue of the kidney or liver was added to the culture media. These spiral organisms, or spirochetes, as they are sometimes called, are actively motile and stain with difficulty. They can be found in all diseased organs and tissues in the earlier stages of the disease, but not always in the later stages. They are readily destroyed by drying, and are killed by the ordinary disinfectant solutions such as bichloride of mercury 1 : 1000 and carbolic acid 5 per cent.

Path of infection

The infection takes place through small injuries or cracks in the skin or mucous membranes, and is spread, in the vast majority of cases, through sexual intercourse. On this account syphilis has been termed a venereal disease. It is quite possible to become infected in other ways. People with syphilitic sores in the mouth may transmit the infection to others by kissing or from drinking-glasses or eating-utensils that they have used. Wet-nurses may become infected by nursing a child that is infected. Physicians may become infected in the performance of professional duties, as in the examining of patients and in the attendance of women in confinement. Nurses can be infected from the sores of patients under their care. This kind of infection is, fortunately, not very common, and may be prevented entirely by careful disinfection of the hands after attending such cases, or by the use of rubber gloves. Children may be infected in the uterus or, during labor, from sores in vagina.

Infection manifests itself first by a sore called a

Manifestation of the disease

chancre, which develops from three to six weeks after exposure. It may be located anywhere on the body, but is always at the point where infection entered. The organisms are at first localized in the primary sore, but very soon spread to the glands near by, and then to the blood, causing a general infection. The

Fig. 16.—Treponema pallidum in smear from secretion of a fresh, hard chancre. The dark spots represent the red blood-cells; the light, wavy lines the spirochetes. × 1000. (*After Lenhartz.*)

result is a general skin eruption, sore throat, fever, and anemia,—symptoms that develop in from six to twelve weeks after the chancre, and mark the beginning of the secondary stage. The disease is most infectious at this period. Later the spirochetes become localized in certain tissues, particularly the brain and spinal cord, and lead to the formation of nodules

which have a tendency to become soft and cheesy. A nodule of this sort is called a gumma and is characteristic of the tertiary stage of syphilis.

Diagnosis The presence of syphilis may be detected by examining the serum from the sores for spirochetes. This is done by mixing the serum with a drop of india-ink, which makes the colorless spirochetes easier to see. A better method, and one now in general use, is the Wassermann reaction, which aims to detect the presence of the immune substances that develop in the blood soon after infection has taken place. The technique of the reaction is complicated and will not be taken up here; suffice it to say that it is successful in from 90 to 95 per cent. of the cases.

Luetin reaction Killed cultures of the spirochetes may also be utilized in diagnosis by injecting a very small amount of the culture into the superficial layers of the skin. This is called the luetin test, and was devised by Dr. Noguchi. A successful or positive test is shown by the development of a hard, inflamed nodule at the point of injection, and is due to the hypersensitiveness of the skin to the syphilitic poison. The test is of value only in the later stages of the disease.

The Spirochete of Relapsing Fever.

The cause of relapsing fever is a group of spirochetes, the individual members of which differ in minor details in the various countries where the disease prevails. The spirochetes are long, delicate

threads with 4 to 10 spirals and 1 flagellum which propels them about actively. They can be found in the blood of those sick with the fever. At present the infection is most widespread in India and Africa, but sixty to seventy years ago epidemics occurred in this country.

People infected with the spirochetes develop a fever of relapsing type. First there is a period of fever lasting five to seven days, then a period of remission of the same duration. It is spread by insects or ticks which become infected by sucking the blood of patients having the disease. One attack usually confers immunity.

In preventing the spread of the disease it is important to isolate the patient and disinfect the bedding, clothing, and apartments. Particular attention should be given to the extermination of bedbugs.

Vincent's Angina.

This is an infectious disease of the gums, mouth, or throat, characterized either by the formation of a membrane which may be identical with the diphtheritic membrane, or by ulcerations which have a punched-out appearance. In smears made from the membrane or ulcers, large, fusiform bacilli, broad in the middle, with tapering ends and long spirilla, are constantly found and are supposed to be the cause of the infection. It is the belief now that the spirilla are but a later stage in the development of the fusiform bacilli. As

both forms are difficult to cultivate, the diagnosis must be made by examining smears made directly from the throat. These organisms may be present with the bacilli of true diphtheria, and are said to aggravate the infection. (See Fig. 11, page 89.)

The disease is usually mild and responds fairly promptly to local treatment, but in some cases where the nature of the infection has not been recognized and properly treated, the ulceration and destruction of tissue in the throat may be extensive. It is spread directly from person to person through the secretions from the mouth. The danger of becoming infected is not great.

Malarial Fever.

Malarial fever is an acute infection caused by a protozoan parasite. It is characterized by intermittent chills and fever and sweats, and accompanied by anemia. There are three types of the fever caused by three species of the parasite: the tertian type, with chill and fever every third day; the quartan, with chill and fever every fourth day; and the estivo-autumnal, with an irregular fever like typhoid.

The disease is transmitted from one person to another by the female mosquito of the genus Anopheles. They can be distinguished from the ordinary mosquito, the Culex, by their position when they alight. The body of the Culex is always parallel to the surface, while the body of the Anopheles forms a sharp angle with it. When the Anopheles feeds on

infected blood the malarial parasites are taken into the stomach and undergo reproduction. After seven to ten days they find their way to the salivary glands. When the mosquito bites man the parasites are excreted with the saliva into the wound. In the blood the parasites enter and develop within the red blood-cells. As they grow they fill more and more of the corpuscle and finally become segmented into smaller

Fig. 17.—Plasmodium vivax, parasite of tertian fever. In the upper row and on left of lower row, various stages of intracorpuscular development; the two last figures in lower row are free sexual individulas, microgametocytes (sperm cells), which are about to set free the microgametes, or males. (After *Reinhardt.*)

bodies that are to become parasites. When this development is complete, requiring forty-eight or seventy-two hours, depending upon the type of parasite, the red blood-corpuscle is ruptured and the segments set free in the circulating blood, causing the chill and fever that are so characteristic of the disease. In this way more and more blood-cells are attacked and destroyed, which explains the anemia.

The diagnosis is made by finding the parasites in the blood. They can be found by examining either fresh preparations or stained specimens. In the former the parasites can be seen inside the red blood-corpuscles as colorless bodies containing granules of pigment that are in active motion. In the stained specimens the parasites are motionless, but are much more distinctly seen.

The spread of malaria is controlled by all measures that aim at the extermination of the mosquito. As the mosquito lives and breeds in swamps and ponds, attention should be directed to these places first. The larvæ from which the mosquito develops live and grow near the surface of stagnant water. If oil is spread on the water the larvæ cannot hatch out into mosquitoes. Swamps, when it is practical to do so, should be drained or filled in. In districts where malaria is known to exist, the house should be screened.

Trypanosomes.

A trypanosome is a long micro-organism with spirally twisted body. On one side is a membrane the edge of which is cord-like and extends beyond the body to form a whip or flagellum. The wave-like movements of the membrane and the movements of the flagellum propel the trypanosome about. The protoplasm is granular and contains two nuclei. Reproduction takes place by a longitudinal splitting of the whole cell body. The life cycle is not clear, but in

some species at least there is development in an intermediate host, generally some species of fly.

There are about 60 species of trypanosomes, many of which are pathogenic for animals, but only 2 are known to cause disease in man. The *Trypanosoma gambiense* is the cause of the sleeping sickness, a disease prevalent in equatorial Africa. One of the natural hosts of the parasite is the crocodile, and a species of fly, the *Glossura palpales,* that feeds on the blood of these animals, transmits the infection to human beings. Trypanosomiasis, or the sleeping sickness, is a chronic disorder marked by fever, wasting, and lethargy. The parasites can be found in the blood, but more often in the cerebrospinal fluid. No way of establishing an immunity is known.

CHAPTER XII.

DISEASES CAUSED BY UNKNOWN MICRO-ORGANISMS

Under this head come a number of diseases such as scarlet fever, measles, German measles, smallpox, and chicken-pox, which are often classed together under the name of exanthemata, because they are all characterized by skin eruptions and symptoms of general infection.

Scarlet Fever.

The infection almost always occurs from direct contact; entering the sickroom may be exposure enough to cause the disease. Objects which the patient has touched will transmit the infection, such as linen, clothing, furniture, and playthings. Physicians and nurses sometimes carry the infection, although they themselves may not be affected. Milk has been known to carry the infection and cause serious epidemics. The milk in such cases is infected at the dairy by someone who has the disease. The infection may be transmitted at any time during the disease, but especially during the period of desquamation.

In order to prevent it from spreading, the sickroom in private homes should be as far away as possible from the room occupied by other members of the family. Admission to the room should be denied to

everyone except the physician and the nurse. The physician should wear a gown and cap when entering the room, and should pass directly out of the house after visiting the patient. The nurse too should wear a gown over the uniform and a cap over the hair, both being removed when it is necessary to go to other parts of the house. During the period of desquamation skin should be kept anointed with plain or carbolized vaselin, as preferred, in order to keep the particles of skin from spreading about. Quarantine may be raised when the desquamation has completely ceased. Before the patient is discharged a full bath in weak bichloride of mercury solution, 1 : 10,000, should be given, taking particular care to cleanse the hair. The room and contents should be disinfected after the manner already described.

Measles.

Measles is a contagious and infectious disease that generally occurs during childhood, although adults may contract it. It spreads with great rapidity and generally in epidemics. The specific agent of infection is probably inhaled, causing the first symptoms to appear in the nose and throat.

The infectious material is undoubtedly in the secretions of the nose and throat of the sick patients. It may be spread by the attendants on the patient, by furniture, hangings, carpets, by flies and insects. In preventing the spreading of the disease special atten-

tion should be given to destroying the secretions from the nose and throat. These should be collected in paper bags and burned. The patient should be quarantined until the skin and mucous membranes are clear. After recovery the room should be disinfected.

Rubella, or German Measles.

The infection is very much like measles, but is usually not so severe. In preventing its spread the same precautions should be taken as in measles.

Variola, or Smallpox.

Smallpox is an acute infectious disease characterized by a skin eruption that passes successively through the stages of papule, vesicle, pustule, and crust, and usually leaves a depressed scar. The infectious agent is in the pustules, secretions, excretions, and in the breath. The scales are particularly infectious, forming a part of the dust in the room and becoming attached to the furniture, hangings, and clothing. The poison is very tenacious and remains virulent for months.

In caring for smallpox patients the first thing to do is to isolate them, preferably in a building removed from other dwellings, because of the possibility of the virus being carried in the air. The strictest quarantine should be enforced not only of the patients, but of the attendants. Everyone that has been exposed to the contagion should be vaccinated and kept under obser-

vation for sixteen days. During the illness the discharges from the mouth, nose, and intestines should be disinfected. The quarantine must be maintained until the skin is entirely free from crusts and scales.

The method and principles of immunization to smallpox have been described under the subject of immunity.

Chicken-pox, or Varicella.

This is an acute infectious disease of children. It is spread in the same manner as smallpox, but to prevent its spreading the precautions need not be so rigidly enforced, because it is not so serious an infection. The patient is kept from contact with other children, and after recovery the room should be disinfected.

Rabies, or Hydrophobia.

Rabies is a disease common among animals, particularly dogs, although cats, cattle, and horses may be infected. It is transmitted from one animal to another, and to man through the saliva from the bites of rabid animals. The poison acts upon the tissue of the brain and spinal cord, being carried there along the nerve-trunks. The incubation period is from forty to sixty days.

In animals the disease begins with a stage of excitement and restlessness, followed by depression, difficulty in swallowing, and paralysis. In man there is first headache and depression, later difficulty in swal-

lowing, and spasm of the muscles of respiration. The spasms are very painful and may be induced even by the sight of water. This is the origin of the name hydrophobia, which means fear of water.

All efforts to find the cause of the infection in the brain and spinal cord have been fruitless. Peculiar bodies, called Negri bodies, are quite constantly found in the brain and spinal cord, which many believe are parasites belonging to the animal kingdom, and classed as protozoa. The diagnosis of rabies can be made either by finding the Negri bodies or by reproducing the disease in rabbits by inoculating them in the brain with portions of the spinal cord of rabid animals.

Immunity

It is due to the studies of Pasteur that we are able to immunize against rabies. He found that the virus of rabid dogs could be intensified by inoculating a series of rabbits until the inoculation period could be shortened to six or seven days. The spinal cords of rabbits inoculated in this way contain the virus in its most concentrated form, and is spoken of as the fixed virus.

The fixed virus may be attenuated by drying the spinal cords and, if human beings are now inoculated with portions of the tissue, beginning first with the most attenuated and then with more and more virulent tissue, an active immunity is established. This is the method now in use in the treatment of persons who have been bitten by rabid dogs, and it can be applied during the forty- to sixty- day incubation period. It has proven very successful. In the last ten

years 50,000 people have been immunized in this way, with failure in only 1 per cent.

Yellow Fever.

This is an acute infectious disease the cause of which is not known, but it has been proved that the infection may be transmitted by a certain kind of mosquito called the *Stegomyia fasciata*. The blood of yellow-fever patients contains the virus for a period of three days during the sickness, and as the stegomyia feeds on the blood of the patient during this time, it becomes infected. The mosquito cannot transmit the infection at once, not until twelve days have elapsed. If it bites healthy people now, it infects them and the fever develops after an incubation period of five days.

Yellow fever is primarily a disease of the tropical climate, particularly of the Spanish-American countries. It is occasionally imported to the temperate climate, as numerous epidemics in the seaport cities of the United States testify. To prevent the spread of the disease efforts must be directed to the destruction of the breeding places of the mosquitoes, and to prevent them from biting yellow-fever patients. The former means a complete cleaning up and draining of the swamps and marshes. All yellow-fever patients must be screened to prevent the mosquitoes from biting them. In countries where the infection prevails, all houses should be screened. Such measures as these rendered the Panama Canal Zone, formerly a hotbed of yellow fever, a safe place in which to live.

Distribution

Prevention

Acute Anterior Poliomyelitis.

This is an acute infectious disease affecting the gray matter of the spinal cord, causing paralysis of groups of muscles. It occurs in sporadic and epidemic form. It affects children particularly, and while the mortality rate is low the deformities resulting from the paralysis are very disfiguring.

During the past year Drs. Flexner and Noguchi, at the Rockefeller Institute in New York, have been successful in cultivating an organism from the spinal cords of fatal cases of this disease. By inoculating monkeys with the cultures they have reproduced the disease and, after the death of the animals, have recovered the organism again from the spinal cord.

How the infection is spread is not known. It is assumed that the discharges from the nose and throat are infectious; so they should be collected and destroyed. As an added precaution, the patient should be isolated. No method of immunization is known.

Acute Rheumatic Fever.

This disease is generally conceded to be infectious, but the cause is as yet unknown. Several kinds of bacteria, among them the streptococci and staphylococci, have been described as its cause. They have been cultivated from the joints, blood, tonsils, and heart-valves of rheumatic-fever patients. An infection very much like rheumatic fever has been produced by inoculating animals with the cultures. It is not cer-

tain, however, whether these organisms are present as the actual cause of the disease, or are only secondary invaders.

Mumps.

This is an acute infectious disease affecting the salivary glands in infants and young adults. It is contagious, being spread directly from one patient to another. The infectious agent is unknown.

Typhus Fever.

While characteristic bacilli have been described in the blood of patients sick with this disease, efforts to cultivate them have not been successful. The infection can be transmitted to monkeys by injecting them with the blood of patients. The infection can be carried by the body louse (*Pediculus vestimentorum*).

CHAPTER XIII.

THE TECHNIQUE OF PREPARATIONS FOR AND THE COLLECTION OF MATERIAL FOR BACTERIOLOGICAL EXAMINATION.

It is not strictly a part of the nurse's work to collect specimens for bacteriological examination, but sometimes the occasion arises when the nurse can render valuable assistance by knowing how to do these things. On the other hand the preparation of the patient for bacteriological procedures, such as punctures for aspirating fluids and the making of cultures from the circulating blood, is quite properly within the duties of the nurse. The directions that follow will serve as a guide, but may need to be modified or changed according to the ideas of the physician in attendance.

The Collection of Urine.

The collection of specimens

A sterile test-tube plugged with cotton is used to collect the urine, and the urine must be obtained by catheter. The usual technique is followed in preparing the patient, the catheter introduced, and the first part of the urine allowed to escape. The cotton plug is now twisted out of the tube, the mouth of the tube passed through the flame of an alcohol lamp, and the urine allowed to fill the tube one-half or three-fourths full. The stopper is then replaced and the tube kept in the upright position.

Sputum.

Specimens to be examined for tubercle bacilli should be collected in a clean, wide-mouthed bottle that can be tightly corked to prevent leakage. Sputum to be examined for other kinds of bacteria should be collected in a bottle plugged with cotton and previously sterilized. If the outside of the bottle has been soiled with the sputum, it should be washed off with a 5 per cent. solution of carbolic acid.

Feces.

The stool may be passed directly into a sterile fruit-jar or into a sterile bed-pan, and then transferred to the jar. The specimen may be transferred either by pouring or by means of sterile forceps or a wooden spatula.

Blood for Widal Reaction.

The blood is obtained best by pricking the lobe of the ear with a needle having a cutting edge. The skin should be cleansed with alcohol, and the needle must be sterile. The best way to collect the blood is in a capillary glass tube by placing one end of the tube in the drop of blood and lowering the other end enough to allow the blood to flow in easily until the tube is one-half full. If a capillary tube is not at hand, the blood may be collected on a glass slide or on glazed paper like a calling card. Two or three drops are enough.

Throat Cultures.

Outfits for making throat cultures are supplied by the Bureau of Health in most cities, and consist of a sterile swab in a test-tube and a tube of culture medium. The patient is placed in a good light, the tongue held down by a tongue-depressor or spoon-handle, and the swab rubbed over the inflamed part of the throat. The material on the swab is then rubbed directly over the surface of the culture medium. After use the swab may be burned or replaced in the tube and sent with the culture.

Pus.

When the amount of the pus is sufficient, it may be collected directly into a sterile test-tube. If cultures are made, the swab and culture tube of a throat-culture outfit may be used. The pus is collected on the swab and then rubbed over the culture medium, just as in making a throat culture.

Milk and Water.

Specimens should be collected in glass-stoppered bottles, of 4- or 6- ounce capacity, which are sterile. Specimens of milk should be well mixed before the sample is taken. Specimens of both milk and water must be kept cold and, if it is necessary to send them any distance, they must be packed in ice.

All kinds of specimens should be labeled with

the names of the patient and the physician, the date, and the character of the examination required.

Aspiration of Chest, Blood-cultures.

The technique of making preparations

The preparation of the patient for the aspiration of fluid from the body cavities, for lumbar puncture, and cultures from the blood must be performed with the greatest care, to insure the patient against infection and to prevent the contamination of the specimen with other bacteria, particularly those in the skin.

For aspirations of the chest or joints and for lumbar puncture the skin should be cleansed with benzene and then tincture of iodine applied. For taking cultures from the blood this method is not suitable, because the tincture of iodine discolors the skin so much that the veins cannot be seen clearly. The veins usually selected are at the bend of the elbow. The skin is first washed thoroughly with green soap and water, then with alcohol and ether. A wet bichloride of mercury towel is placed over the skin and allowed to remain for one hour. Before the culture is taken the skin is again washed with ether. A bandage is applied somewhat above the elbow, and tight enough to cause the veins to stand out so that they can be more readily punctured. The blood is drawn into a sterile glass syringe that has been sterilized by boiling in a covered receptacle, which can be brought to the bedside unopened.

GLOSSARY.

Abrasion. A spot rubbed bare of skin or mucous membrane.

Accessory sinuses. Cavities in the bones of the skull, some containing blood and some air.

Aërobic. Requiring air or free oxygen for growth.

Anaërobic. Able to live only in the absence of air or free oxygen.

Anemia. A condition in which the blood is lacking either in quantity or quality.

Aniline dyes. Colors derived by chemical process from coal-tar.

Animalcules. Very small animal organisms.

Antitoxin. A proteid substance developed in the bodies of man or animals that has the power of neutralizing poisons.

Arthritis. Inflammation of a joint.

Bacillus (pl. **bacilli**). A rod-shaped organism belonging to the vegetable kingdom.

Bactericidal. Possessing the power of destroying bacteria.

Bacterins. Killed bacteria suspended in fluid and injected under the skin in the treatment of some diseases. Also called vaccines.

Bacteriology. The study of bacteria.

Bacteriolysins. Substances developed in the body which are capable of dissolving bacteria.

Bacterium (pl. **bacteria**). A unicellular organism belonging to the vegetable kingdom.

Binary fission. The method of multiplication of bacteria in which the organism splits in half.

Carbohydrates. A compound composed of carbon, hydrogen, and oxygen.

Carrier. A person, not sick with any disease, who carries disease-producing organisms in the body and is capable of infecting others with them.

Cell. The smallest unit of structure in plant and animal life.

Chancre. The primary sore at the point of infection in syphilis.

Cellulitis. An inflammation in the soft tissues of the body.

Coccus. A bacterium having a spherical shape.

Colony. A mass of micro-organisms of the same kind that has developed from one organism.

Contagion. The transmission of disease by mediate or immediate contact.

Culture. A mass of micro-organisms growing on laboratory culture media.

Cystitis. Inflammation of the urinary bladder.

Deodorant. A substance that destroys objectionable odors.

Disinfectant. A physical or chemical agent that destroys bacteria.

Empyema. A collection of pus in the pleural cavity.

Endocarditis. An inflammation of the lining of the heart.

Endotoxin. A poison retained in the body of a bacterium and set free when the bacterium disintegrates.

Enzyme. An unorganized ferment formed in the bodies of plants and animals capable of splitting complex substances into simpler forms without being changed itself.

Erysipelas. An acute spreading infection in the skin.

Etiology. The study of the causes of disease and the way disease is transmitted.

Fermentation. The decomposition of complex substances into simpler forms by the action of a ferment.

Flagellum (pl. flagella). A whip-like process extending from the body of a bacterium which propels the organism about.

Filtration. The passage of fluid through a filter to remove the solid particles.

Hemoglobin. The coloring matter contained in the red blood-corpuscles which gives the blood its red color.

Immunity. The resistance of the body to disease.

Incubation. The period between the entrance of disease-producing bacteria into the body and the signs and symptoms of disease.

Infection. The entrance into the body of bacteria resulting in injury or disease.

Inhibition. The arrest or restraint of bacterial growth.

Inoculate. To put infectious material into the body to produce disease or into culture media to produce bacterial growth.

Larva (pl. larvæ). The stage of insect development after it leaves the egg in which it resembles a worm.

Lesion. An abnormal condition of any tissue or organ due to injury or disease.

Leucocyte. The white blood-corpuscle of the blood.

Luetin reaction. A skin test for the detection of syphilis.

Lumbar puncture. The introduction of a needle into the space around the spinal cord for the removal of the cerebrospinal fluid.

Medium (pl. media). The material used for the cultivation of bacteria.

Meningitis. An inflammation of the membranes covering the brain and spinal cord.

Morphology. The study of the form and structure of bacteria.

Mycelium. The thread-like processes of fungi.

Necrosis. The death of tissue.

Negri bodies. Minute bodies found in the brain of persons and animals infected with rabies.

Nucleus (pl. nuclei). The spherical body found in cells which controls its life and activity.

Opsonin. A substance in the blood-serum which makes bacteria more easily absorbed by the leucocytes.

Orchitis. An inflammation of the testicle.

Organic. Relating to substances derived from living organisms.

Osteomyelitis. An inflammation of the medullary cavity of bone.

Otitis media. An inflammation of the middle ear.

Papule. A small, solid elevation of the skin.

Parasite. A plant or animal that lives on or in another living organism.

Pasteurization. The arrest of bacterial growth by heat.

Pathogenic. Disease-producing.

Phagocyte. The white blood-corpuscle of the blood that envelops and destroys bacteria.

Pericarditis. An inflammation of the covering of the heart.

Pseudopod. A transient protrusion of the protoplasm of an ameba.

Protozoön (pl. protozoa). A unicellular animal organism.

Prophylaxis. The prevention of disease.

Pyogenic. Pus-producing.

Puerperal fever. An infection starting in the uterus after childbirth.

Pustule. A small elevation of the skin containing pus.

Quarantine. Isolation on account of suspected contagious disease.

Saprophyte. An organism capable of living on dead matter.

Septicemia. The condition resulting from the invasion of the body by bacteria and the absorption of the poisons produced by them.

Spirochete. A spiral or corkscrew-shaped organism.

Sterile. Free from micro-organisms.

Suppuration. The formation of pus.

Tenesmus. Ineffectual straining at stool.

Tuberculin. A preparation made from tubercle bacilli and containing their toxins.

Vaccine. See bacterin.
Vesicle. A small elevation of the skin containing serum.
Vacuole. A cavity in the protoplasm of a cell.
Virus. An animal poison capable of producing disease.

Widal reaction. A blood-test for the detection of typhoid fever.
Wassermann reaction. A blood-test for the detection of syphilis.

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